Food and Agriculture Organization of the United Nations

2022

THE STATE OF THE WORLD'S FORESTS

FOREST PATHWAYS FOR GREEN RECOVERY AND BUILDING INCLUSIVE, RESILIENT AND SUSTAINABLE ECONOMIES

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MYANMAR. A Rohingya refugee volunteer watering plants inside a refugee camp in Cox's Bazar. He has been engaged with FAO's planting activities aimed at restoring degraded forests since 2018.

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Food and Agriculture Organization of the United Nations
Rome, 2022

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KEY MESSAGES

Headlines

There will be no healthy economy on an unhealthy planet. Environmental deterioration is contributing to climate change, biodiversity loss and the emergence of new diseases. Forests and trees can play crucial roles in addressing these crises and moving towards sustainable economies.

Three interrelated pathways involving forests and trees can support economic and environmental recovery. These are (1) halting deforestation and maintaining forests; (2) restoring degraded lands and expanding agroforestry; and (3) sustainably using forests and building green value chains.

The world will need more renewable materials because of a growing population and the need to reduce environmental impacts. The forest sector can and must drive a transition to the more efficient and circular use of biomaterials with higher value added.

Forest and farm producers need more incentive to scale up green recovery. They must derive substantial tangible benefits from restoring and sustainably managing forest and tree resources.

The forest pathways can contribute to building inclusive, resilient and sustainable economies. Doing so optimally will require shifts in policies to maximize synergies among the pathways and between agriculture and forestry across agrifood systems and to encourage private sector investments.

➔ **Trees, forests and sustainable forestry can help the world recover from the COVID-19 pandemic and combat looming environmental crises such as climate change and biodiversity loss**. But this requires societies to better recognize the considerable value of forests and their crucial roles in building inclusive, resilient and sustainable economies.

➔ **Three pathways involving forests and trees offer means by which societies, communities and individual landowners, users and managers can derive more tangible value from forests and trees** while addressing environmental degradation, recovering from crises, preventing future pandemics, increasing resilience and transforming economies:

1. *Halting deforestation and maintaining forests* could avoid emitting 3.6 +/- 2 gigatonnes of carbon dioxide equivalent ($GtCO_2e$) per year between 2020 and 2050, including about 14 percent of what is needed up to 2030 to keep planetary warming below 1.5 °C, while safeguarding more than half the Earth's terrestrial biodiversity.
2. *Restoring degraded lands and expanding agroforestry* – 1.5 billion ha of degraded land would benefit from restoration, and increasing tree cover could boost agricultural productivity on another 1 billion ha. Restoring degraded land through afforestation and reforestation could cost-effectively take 0.9–1.5 $GtCO_2e$ per year out of the atmosphere between 2020 and 2050.
3. *Sustainably using forests and building green value chains* would help meet future demand for materials – with global consumption of all natural resources expected to more than double from 92 billion tonnes 2017 to 190 billion tonnes in 2060 – and underpin sustainable economies.

➔ **The three pathways are mutually reinforcing.** When synergies are maximized, the pathways can provide some of the highest returns in the form of climate and environmental benefits while also enhancing local sustainable development potential, adaptive capacity and resilience.

➔ **Shifts in policies are needed to divert financial flows away from actions that harm forests and to incentivize investment in conservation, restoration and sustainable use.** Finance for the three forest pathways needs to at least triple (to more than USD 200 billion per year for forest establishment and management alone) by 2030 to meet climate, biodiversity and land degradation neutrality targets. REDD+ frameworks have advanced in recent years and implementation and finance are scaling up. This and other related results-based payment schemes could play a key role in supporting developing countries to move along the forest pathways.

➔ **Smallholders, local communities and Indigenous Peoples own or manage nearly half – 4.35 billion ha – of the world's forest and farm landscapes and will be crucial for scaling up implementation of the pathways.** According to one estimate, smallholders on such lands generate a gross annual income of up to USD 1.29 trillion. More than 8.5 million producer organizations now exist to help local actors participate in and support a green recovery.

➔ **Companies in forest-based value chains will be essential partners in the development of circular economies.** Many are already expanding the range of forest products as substitutes for materials with higher greenhouse-gas emissions and increasing processing efficiency. Local forest growers and processors can obtain more benefit by strengthening links with buyers and developing capacity through producer organizations.

➔ **Scaling up action on the three forest pathways carries risks, especially for smallholders, whose investments in them could fail in the absence of supportive policies and institutions.** Risks associated with climate change, such as increased vulnerability to fire, pests and drought, also need to be managed.

➔ **Starting points for moving swiftly along the pathways** may include:

1. directing funding for recovery towards long-term policies aimed at creating sustainable and green jobs and further mobilizing private sector investment;
2. empowering and incentivizing local actors, including women, youth and Indigenous Peoples, to take a leading role in the forest pathways;
3. engaging in awareness raising and policy dialogue on sustainable forest use as a means for simultaneously achieving economic and environmental goals; and
4. maximizing synergies among the three forest pathways and between agricultural, forestry, environmental and other policies and minimizing trade-offs.

FOREWORD

The COVID-19 pandemic has made the eradication of hunger and poverty both more challenging and more urgent. Recovery needs to address the impacts of the pandemic and related containment measures, which have hit vulnerable people especially hard.

Even before the pandemic, much of humanity's progress had come at considerable cost to the environment. A combination of intensified agricultural production processes and the clearing of forests to produce ever more food and other agricultural goods has led to environmental degradation and is contributing to the climate crisis. Continuing along current agrifood production pathways is unviable.

Transformation of global agrifood systems has started, as evidenced by the 2021 United Nations Food Systems Summit and related initiatives. There is a need to recover both from a short-term crisis – the human health pandemic – and the longer and deeper emergency caused by a "planetary health" crisis.

There are alternative pathways for the future of food and agriculture that should be considered. FAO has done this through its Strategic Framework 2022–31 around the four fundamental aspirations of "better production", "better nutrition", "a better environment" and "a better life for all – leaving no one behind". FAO has also put forward a vision for sustainable agrifood systems based on five principles and 20 interrelated actions, applicable across sectors and scales.

In this report, we explore three forest and tree-based pathways that complement other actions aimed at achieving more efficient, more inclusive, more resilient and more sustainable agrifood systems, namely: halting deforestation and maintaining forests; restoring degraded lands and expanding agroforestry; and sustainably using forests and building green value chains. The balanced, simultaneous pursuit of these pathways can help address the crises facing people and the planet while also generating sustainable economic benefits, especially in (often remote) rural communities. Forests and trees are valuable assets that, through the forest pathways, can support recovery and build more resilient local economies. The pathways are set out on the premise that solutions to interrelated planetary crises have economic, social and environmental implications that need to be addressed holistically.

Overall, the outcomes of the 2021 Glasgow Climate Change Conference supported all three of the forest pathways. More than 140 countries have pledged, through the Glasgow Leaders' Declaration on Forests and Land Use, to eliminate forest loss by 2030 and to support restoration and sustainable forestry. To this end, an additional USD 19 billion has been allocated to help developing countries achieve these objectives. The area of forest and farm landscapes managed by family farmers, smallholders, forest communities and Indigenous Peoples exceeds 4 billion hectares, and these actors are crucial for the effective implementation of the pathways.

This report sets out the steps by which the world can further pursue the three forest pathways, a green recovery and the move towards more circular economies. There is no time to lose – we need to act now to keep the global temperature increase below 1.5 °C, reduce the risk of future pandemics, ensure food security and nutrition for all, eliminate poverty, conserve the planet's biodiversity and offer young people hope of a better world and a better future for all. FAO is committed to supporting Member Nations explore the potential of the three forest pathways for further investment and effective implementation, in close collaboration with partners.

Qu Dongyu
FAO Director-General

METHODOLOGY

The State of the World's Forests 2022 (SOFO 2022) has been prepared by the FAO Forestry Division.

The content of SOFO 2022 derives from published literature, studies commissioned for the purposes of the report, online webinars on relevant topics involving experts worldwide, original data analysis, and expertise and experiences from country-level, regional and global projects undertaken by FAO. The report was prepared by a technical writing team at FAO comprising coordinators, authors and other contributors, and an editor. For each chapter, a coordinator worked with authors and other contributors to ensure continuity within and between chapters and to identify key findings. The overall coordinator liaised with the chapter coordinators, oversaw the writing, editing, review and messaging processes, and provided additional inputs.

An advisory panel led by FAO and consisting of senior managers and experts at diverse institutions guided report development. This panel reviewed the outline of the report (as developed by FAO) and its thematic focus and provided oversight and feedback to the writing team. Some members of the advisory panel also provided formal reviews of the first draft.

The writing team produced a number of interim outputs, including a detailed outline and first and final drafts. The first draft was subject to single-blind review by more than 70 experts drawn from within and beyond FAO. It was also shared with FAO regional and subregional offices for review and further comment, and the draft findings were presented to Members through their Permanent Representations to FAO and resulting comments addressed. The writing team revised the draft in light of these reviews and comments to produce the final draft. Finally, the report underwent executive review and clearance at FAO.

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ACRONYMS AND ABBREVIATIONS

°C	degree(s) Celsius
CIFOR-ICRAF	Center for International Forestry Research and World Agroforestry
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COP	Conference of the Parties
COVID-19	coronavirus disease
EFT	ecological fiscal transfer
EID	emerging infectious disease
ESVD	Ecosystem Services Valuation Database
ETS	emissions trading system
EUR	euro(s)
FAO	Food and Agriculture Organization of the United Nations
FLR	forest and landscape restoration
FRA	Global Forest Resources Assessment
FSC	Forest Stewardship Council
GDP	gross domestic product
GFPM	Global Forest Products Model
GGW	Great Green Wall
GHG	greenhouse gas
Gt	gigatonne(s)
GtC	gigatonne(s) of carbon
ha	hectare(s)
Int$	international dollar(s)
IRW	industrial roundwood
ITMO	internationally transferred mitigation outcome
kg	kilogram(s)
km	kilometre(s)
MDB	multilateral development bank
MRV	monitoring, reporting and verification
Mt	megatonne(s)
NDC	nationally determined contribution
NWFP	non-wood forest product
ODA	official development assistance
PEFC	Programme for the Endorsement of Forest Certification
PES	payments for ecosystem services
RBP	results-based payment
REDD+	reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks
SDG	Sustainable Development Goal
SEEA	System of Environmental-Economic Accounting
SEEA-EA	System of Environmental-Economic Accounting Ecosystem Accounting
SOFO	State of the World's Forests
t	tonne(s)
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States dollar(s)
VPA	voluntary partnership agreement
VSLA	village savings and loans association

EXECUTIVE SUMMARY

1 – CAN FORESTS AND TREES PROVIDE MEANS FOR RECOVERY AND INCLUSIVE, RESILIENT AND SUSTAINABLE ECONOMIES?

Humanity is facing multiple global threats.

- These include a pandemic and related economic hardship, food insecurity, poverty, climate change, conflicts, land and water degradation, and biodiversity loss.

The world needs solutions at scale that are cost-effective and equitable and can be implemented rapidly, and forests and trees have clear potential.

- Societies could make better use of forests and trees to simultaneously conserve nature, better provide for human well-being, and generate income, particularly for rural people.

Three forest-based pathways warrant close examination as means for tackling local to global challenges.

- These are:
  1. halting deforestation and maintaining forests;
  2. restoring degraded lands and expanding agroforestry; and
  3. sustainably using forests and building green value chains.
- This report outlines the roles and values of forests and trees; examines the benefits and costs of the pathways and ways of integrating them into existing and emerging policies; assesses the potential for additional finance for the pathways; and explores how best to enable and scale up adoption, where appropriate, by decision-makers at the national level and on the ground.

2 – FORESTS AND TREES PROVIDE VITAL GOODS AND ECOSYSTEM SERVICES BUT ARE UNDERVALUED IN ECONOMIC SYSTEMS

Forests are resources of global significance.

- They cover 31 percent of the Earth's land surface (4.06 billion ha) but the area is shrinking, with 420 million ha of forest lost through deforestation between 1990 and 2020. The rate of deforestation is declining but was still 10 million ha per year in 2015–2020. Some 47 million ha of primary forests was lost between 2000 and 2020.
- Planted forests cover 294 million ha (7 percent of the global forest area), with the area increasing by a rate of just under 1 percent per year in 2015–2020, down from 1.4 percent per year in 2010–2015. The area of other wooded land fell by nearly 1 percent between 2000 and 2020, but the area of other land with tree cover (comprising trees in urban settings, tree orchards, palms and agroforestry landscapes) increased by more than one-third between 1990 and 2020. There is at least 45 million ha of agroforestry land, with an increasing trend.
- Forests provide habitat for 80 percent of amphibian species, 75 percent of bird species and 68 percent of mammal species, and tropical forests contain about 60 percent of all vascular plant species. More than 700 million ha of forest (18 percent of the total forest area) is in legally established protected areas. Nevertheless, forest biodiversity remains under threat from deforestation and forest degradation.
- Climate change is a major risk factor for forest health. For example, there are indications that the incidence and severity of forest fires and pests are increasing.

Forests are crucial for mitigating climate change.

- Trees and forests are major means for combating climate change. Forests contain 662 billion tonnes of carbon, which is more than half the global carbon stock in soils and vegetation. Despite a continued reduction in area, forests absorbed more carbon than they emitted in 2011–2020 due to reforestation, improved forest management and other factors.
- Forests have a range of other impacts on climate change, such as by affecting albedo and atmospheric water vapour and emitting aerosols. Deforestation in the Amazon and African tropics could have major regional impacts on rainfall and therefore on rainfed agriculture. The local to regional impacts of forests on climatic conditions can be important; for example, trees in urban areas reduce land surface temperatures in Central Europe in summer and during heat extremes by as much as 12 °C.

Societies benefit from and are highly dependent on forests.

- It is estimated that more than half of world gross domestic product (USD 84.4 trillion in 2020) depends moderately (USD 31 trillion per year) or highly (USD 13 trillion per year) on ecosystem services, including those provided by forests.
- The wealth represented by certain forest ecosystem services (recreation and hunting, habitat, the provision of non-timber forest products, and water services) is estimated at USD 7.5 trillion, which is 21 percent of the total wealth in land assets and about 9 percent of world gross domestic product. The absence of natural asset stock in national wealth accounting risks policy errors, with a decline in natural assets likely to affect other assets in the longer term. Efforts are underway to improve estimates of the value of nature, including forests.
- About 33 million people – 1 percent of global employment – are estimated to work directly in the formal and informal forest sector. The sector contributed (directly, indirectly and induced) more than USD 1.52 trillion to world gross domestic product in 2015.
- One-third of the global population (about 2.6 billion people) relies on wood and other traditional fuels for household cooking. Traditional woodfuel, however, is a significant contributor to household air pollution, which is responsible for 1.63 million–3.12 million premature deaths per year.
- One study estimates that 3.5 billion–5.76 billion people use non-timber forest products for own use or to support livelihoods. Wild-harvested forest foods add to the food security and nutrition of forest-adjacent people, especially in remote areas in the tropics and subtropics.

Many forest-proximate people obtain insufficient benefits from forests.

- An estimated 4.17 billion people – 95 percent of all people outside urban areas – live within 5 km of a forest, and 3.27 billion live within 1 km. In many tropical countries, forest-adjacent people earn about one-quarter of their income from forests.
- There is likely a strong relationship between forest proximity and extreme poverty, given that 80 percent of the extreme poor live in rural areas. Evidence is well established that forests and other tree-based systems support poor people to improve their well-being and mitigate risks, but their role in helping people move permanently out of poverty is less well documented.
- About three-quarters (73 percent) of forests globally were owned publicly in 2015 and 22 percent were owned privately. There has been a slow increasing trend in the proportion of management rights to publicly owned forest held privately, from 2 percent in 1990 to 13 percent in 2015. Local, tribal and indigenous communities are legally recognized as owning at least 447 million ha of forest (as of 2017).

The COVID-19 pandemic had a significant impact on forest value chains and trade in early 2020. Most sectors rebounded quickly, but the risk of future pandemics remains.

- For example, the production of graphic papers such as newsprint dropped by more than 11 percent in 2020 (exacerbating an ongoing trend) but grew for certain other papers, such as those used for packaging. The pandemic may have longer-term impacts on woodfuel, having pushed an estimated 124 million more people into extreme poverty. There is evidence of increased woodfuel use in some countries during the pandemic, and projections suggest that more than 1 billion people in sub-Saharan Africa will still be reliant on polluting fuels such as charcoal and fuelwood by 2025.
- There is a potential longer-term nexus between forests and disease. More than 30 percent of new diseases reported since 1960 are attributed to land-use change, including deforestation, and 15 percent of 250 emerging infectious diseases have been linked to forests. Deforestation, particularly in the tropics, has been associated with an increase in infectious diseases such as dengue fever and malaria.

3 – THREE INTERRELATED FOREST PATHWAYS COULD CONTRIBUTE TO GREEN RECOVERY AND A TRANSITION TO SUSTAINABLE ECONOMIES

3.1 Halting deforestation and maintaining forest ecosystem services would benefit climate, biodiversity, health and long-term food security

Halting deforestation is potentially one of the most cost-effective actions for mitigating climate change if efforts ramp up.

- All pathways developed by the Intergovernmental Panel on Climate Change consistent with limiting the mean temperature rise to less than 1.5 ºC require that human activities become carbon-neutral by 2050. In addition to rapid decarbonization across economies, significant mitigation will be needed from land-based options. Halting deforestation would both avoid the direct emissions from lost biomass and enable the maintenance of the carbon-absorbing capacity of forests.
- Globally, ecosystems at risk of deforestation or degradation contain at least 260 Gt of irrecoverable or difficult-to-recover carbon, particularly in peatlands, mangroves, old-growth forests and marshes. Unless additional action is taken, an estimated 289 million ha of forests would be deforested between 2016 and 2050 in the tropics alone, resulting in the emission of 169 $GtCO_2e$.
- The latest data confirm that agricultural expansion is driving almost 90 percent of global deforestation. This land-use change responds to multiple underlying drivers, including poverty and unsustainable production practices and consumption patterns.
- Recent estimates suggest that halting deforestation could cost-effectively avoid emitting 3.6 +/- 2 $GtCO_2e$ per year between 2020 and 2050, equivalent to 14 percent of the additional mitigation needed by 2030 to keep planetary warming below 1.5 ºC, depending on how quickly efforts are ramped up. Taking advantage of REDD+ frameworks could facilitate the implementation and financing of these actions.
- Evidence suggests that halting deforestation would generate multiple other local and global benefits – such as biodiversity conservation, disaster reduction, the protection of soils and water and the maintenance of pollination services – that far exceed the cost of halting deforestation. It would also increase the adaptive capacity and resilience of people and ecosystems.

More efficient, productive and sustainable agrifood systems are key for meeting future needs for food while reducing demand for agricultural land, maintaining forests and securing the multiple benefits that forests provide to farming systems.

- An important source of future competition for land stems from the projected growth in global population to 9.7 billion people by 2050. Taking dietary changes and other factors into account, this could mean an increase in food demand of 35–56 percent by mid-century.
- Certain trade practices involving agricultural and forest products could drive deforestation. Although forest area has expanded in several countries worldwide, the deforestation embodied in some of their imports has increased.
- Sustainably increasing productivity could reduce pressure on forestlands caused by heightened food demand. The effectiveness of this approach may vary, however, depending on the nature of the intensification. Synergies and trade-offs need to be addressed.

The cost of global strategies to prevent pandemics based on reducing the illegal wildlife trade, avoiding land-use change and increasing surveillance is estimated at USD 22 billion–31 billion.

- The cost could be lower (USD 17.7 billion–26.9 billion) if the benefits of reduced deforestation for carbon sequestration are considered. This is a small fraction of the cost caused by a pandemic.
- One Health is an integrated approach recognizing that the health of people

is closely connected to the health of animals and the environment. The greater involvement of the forest and wildlife sectors in One Health efforts, and responsible land-use planning, are needed to address some of the underlying drivers of disease emergence.

Multistakeholder engagement is crucial for progress in halting deforestation.

- Various policy responses are addressing the pathway of halting deforestation and maintaining forests. These include decoupling agricultural commodities from deforestation, REDD+, integrated landscape approaches, and strengthening governance and legality.
- Joint public and private initiatives can deliver efficient solutions, and enhanced combinations of landscape approaches with supply-chain governance hold promise as responses to sustainable land-use challenges.

3.2 Forest and landscape restoration and agroforestry help diversify livelihoods and landscapes and increase land productivity

Large areas of degraded land would benefit from restoration involving trees.

- Of the 2.2 billion ha of degraded land identified as potentially (biophysically) available for restoration worldwide, 1.5 billion ha may be best suited for mosaic restoration combining forests and trees with agriculture. A further 1 billion ha of croplands on previous forestlands affected by land-use change would benefit from strategic additions of trees to increase agricultural productivity and the provision of ecosystem services.

Restoration involving trees can provide large environmental and economic benefits.

- According to one estimate, the restoration of 350 million ha of deforested and degraded land by 2030 could deliver a net benefit of USD 0.7–9 trillion and USD 7–30 for every USD 1 invested. Another study estimated that the restoration of degraded land through afforestation and reforestation could cost-effectively take 0.9–1.5 $GtCO_2e$ per year out of the atmosphere between 2020 and 2050.
- An assessment in 42 African countries showed that the benefit of land restoration and conservation for agricultural productivity is 3–26 times greater than the cost of inaction. The restoration of 4 million ha of degraded land in the Sahara and the Sahel created more than 335 000 jobs.
- Restoring degraded ecosystems can enhance the provision of ecosystem services. For example, one meta-analysis found that restoration increased the provision of biodiversity and ecosystem services by an average of 44 percent and 25 percent, respectively, relative to levels in degraded systems.
- Greenhouse-gas emissions from peatlands after they are drained or when they burn are estimated to constitute about 5 percent of the global CO_2 emissions caused by human activities. The economic benefit of peatland restoration is likely to be considerably higher than the cost.
- Fire contributes more than 5 percent of greenhouse-gas emissions from agriculture, forestry and other land use. Integrated fire prevention and suppression as part of landscape management measures are several orders of magnitude less costly than fire-fighting and post-fire restoration.
- Agroforestry systems tend to be more resilient than conventional agriculture to environmental shocks and the effects of climate change. Depending on the system and local conditions, agroforestry can achieve 50–80 percent of the biodiversity of natural forests; increase food security and nutrition by serving as a safety net; and increase crop productivity.

The scaling up of restoration and agroforestry is hindered by the longer time required to obtain profitable returns.

- There is evidence that well-planned and -executed investments in restoration will have net economic benefits. One analysis showed that, even in a worst-case scenario, investing in restoration would return a financial profit in six of nine ecosystem types assessed. Nevertheless, more data are needed to fully

assess the costs and benefits of restoration policies and action.

- Although numerous studies have demonstrated the higher productivity of agroforestry systems, many farmers perceive them as less productive and thus financially risky. On average, agroforestry sees profitable returns after 3–8 years; for annual cropping systems, this period is normally 1–2 years. The greater uptake of agroforestry requires incentives and strategic investments to achieve restoration and improved production objectives.

3.3 Increasing sustainable forest use, and building green value chains, would help meet future demand for materials and support sustainable economies

The world will need more renewable materials.

- The annual global consumption of all natural resources combined is expected to more than double from 92 billion tonnes in 2017 to 190 billion tonnes in 2060 due to increases in population size and affluence. Twenty-five percent of total material demand today is met by biomass and the remainder by non-renewable resources. Annual biomass extraction increased from 9 billion tonnes in 1970 to 24 billion tonnes in 2017 and is expected to reach 44 billion tonnes by 2060.
- World production of roundwood (at 3.91 billion m^3 in 2020) has increased by 12 percent in the last two decades. Demand for forest-based biomass is expected to rise further, driven mainly by construction (with demand in that sector expected to almost triple by 2030) and packaging (with demand expected to double by 2030).

An increase in forest area and sustainable forest management can support a green recovery and a transition to carbon-neutral economies.

- Wood products are associated with lower greenhouse-gas emissions over their entire life cycles compared with products made from non-renewable or emissions-intensive materials. A review of the literature suggests that for every 1 kg of carbon in wood products used in construction to substitute non-wood products, there is an average emission reduction of approximately 0.9 kg of carbon.
- There would be other benefits, too, such as the creation of green jobs – it has been estimated, for example, that wood production and primary processing to meet expected demand for housing in Africa by 2050 would contribute up to USD 83 billion to economies and create 25 million jobs. But unlocking this potential requires investment to develop sufficient capacity.
- Sustainably meeting rising demand will entail an increase in supply through restoration, reforestation and afforestation on degraded lands. It will also require increasing the lifespan of wood products, reducing waste through more efficient processing and the cascading use of forest products, changing consumption patterns, and facilitating a transition to more circular economies. Achieving the maximum technical recycling potential of waste wood and paper would increase the wood-use efficiency ratio in the European wood sector by 31 percent, leading to a concomitant reduction in greenhouse-gas emissions of 52 percent.
- Forest-based bioenergy needs to become more efficient, cleaner and greener – for example, an estimated one-third of woodfuel extraction in the tropics is unsustainable. The gap between demand and sustainable supply can be bridged by the restoration of degraded forests, a move away from the inefficient use of woodfuel for cooking, the environmentally appropriate establishment of tree plantations, improving the use of residues from wood harvesting and processing, and the recovery of post-consumer wood through its cascading use within a more circular economy.

There is potential to mobilize forest-based industries to scale up innovative green value chains.

- The non-food biobased industries are estimated to grow by 3.3 percent per year to 2030, with the projected output valued at USD 5 trillion. A diverse range of emerging forest-based bioproducts has the potential to tap into this

growth, including biochemicals, bioplastics and textiles. There are potential environmental benefits: for example, every 1 kg of carbon of manufactured cellulosic (wood-based) textiles replacing a non-wood textile could avoid carbon emissions of up to 2.8 kg of carbon.

4 – VIABLE OPTIONS EXIST FOR SCALING UP INVESTMENT IN THE FOREST PATHWAYS – WITH POTENTIALLY CONSIDERABLE BENEFITS

Forest investment is well below what is required.

- According to one estimate, total financing for the forest pathways needs to increase threefold by 2030 and fourfold by 2050 for the world to meet climate, biodiversity and land degradation neutrality targets, with the estimated required finance for forest establishment and management alone amounting to USD 203 billion per year by 2050.
- Private sector finance is an important source of funding for forestry, especially the restoration and sustainable-use pathways, but is hard to quantify – it is estimated to account for about 14 percent of current total funding flows for nature-based solutions, including forestry.
- One (2017) estimate suggests that the private sector invests USD 1.5 billion–2 billion per year in plantations and USD 6.5 billion in wood processing in Africa, Asia and Latin America. Investments in value-adding processing facilities can be considered investments in green value chains if the raw materials are sourced sustainably.
- Few COVID-19 pandemic recovery plans have strong components for mobilizing finance for the forest pathways. As of May 2021, green measures accounted for just 2.6 percent of total fiscal spending (i.e. USD 420 billion of USD 16 trillion) related to the pandemic in the world's 87 largest economies. Most recovery programmes still need to be improved to increase their positive impacts on green sectors, including forestry.

All sources of funding – domestic government, private, and official development assistance – will need to be tapped, and new approaches are emerging.

- There are at least five high-potential areas for scaling up implementation of the forest pathways – (1) greening public domestic finance; (2) making climate finance work for forest-based approaches; (3) greening financial markets with regulatory and supervisory tools, with the clear positioning of forest-based approaches; (4) developing pipelines of investment-grade projects; and (5) supporting investment in value-added wood processing in countries of origin.
- Domestic public expenditure on forestry far exceeds official development assistance and (tracked) private finance flows, even in some low-income countries. In 13 sub-Saharan African countries, national governments spend 3.5 times more on forestry than the amount received for this purpose as official development assistance. Ecological fiscal transfers, implemented in only a few countries to date, amount to 20 times the global official development assistance for forestry.
- Investment in forest conservation and restoration appears to be ramping up, including by companies. Many investment instruments with high feasibility in emerging markets are relevant to the forest sector. Blended finance models could help de-risk private sector investments that have significant public value but insufficiently attractive risk–return profiles. Green bonds are developing but, to date, only 3 percent are oriented towards nature-based approaches.
- Many countries recognize the mitigation potential of forests in their recent nationally determined contributions. Many also recognize the role of trees in climate-change adaptation, and there is further potential for countries to integrate forests and trees into their national adaptation plans. A significant number of country targets are conditional on international climate finance, however, highlighting the need for continued support for forest countries.
- Carbon markets are expected to continue growing, driven by carbon-neutrality

pledges and recent decisions under the Paris Agreement on climate change. Results-based payments for REDD+ are evolving to deliver climate-change mitigation results with environmental integrity and adequate benefit-sharing; such payments, and the potential sale of carbon offsets, could improve the financial attractiveness of the three forest pathways. Markets for carbon-neutral and sustainable products require credible monitoring, reporting and verification systems – and these are improving. Climate finance can be used to mobilize additional private sector capital, reinforce domestic policy instruments and support result-based payments.

- Recent developments in financing could support the forest pathways, with national forest financing strategies helping to direct public investment. For example, about 40 new conservation trust funds have been established since 2010, joining 68 previously formed such funds. Many national climate funds offer windows that can support the forest sector.

Redirecting socially and environmentally harmful support, and improving the regulatory environment, could release considerable funding for the forest pathways.

- Scaling up investment will require the strategic use of policy instruments to reorient incentives and boost green markets and financing. For example, repurposing agricultural subsidies – currently almost USD 540 billion per year – to include agroforestry and forestry could help avoid the harmful impacts embodied in 86 percent of such subsidies.
- Countries are adopting standards, regulations and due-diligence requirements to divert financial flows away from actions that harm forests. This trend will likely expand both geographically and in the range of commodities covered.

Getting finance to small-scale producers will be essential for implementing the pathways.

- Less than 2 percent of global climate finance is reaching small farmers, Indigenous Peoples and local communities in developing countries. Nevertheless, new approaches are helping mobilize investment for smallholders, including to reduce perceived risks for investors. Benefit-sharing mechanisms for REDD+ are evolving, but full implementation is limited despite broad interest and readiness efforts in many developing countries.
- More support is needed to develop pipelines of investment-grade projects and programmes to tap into emerging financing opportunities. Options include investment facilities that help small and medium-sized enterprises and others operating in forest value chains to aggregate production, add value and prepare quality projects; and developing and deploying tools that can help inform investment decisions.

5 – SMALLHOLDERS, LOCAL COMMUNITIES AND INDIGENOUS PEOPLES ARE CRUCIAL FOR SCALING UP IMPLEMENTATION OF THE FOREST PATHWAYS

The involvement of smallholders, local communities and Indigenous Peoples in the forest pathways is essential.

- Family farmers account for 80 percent of world food production, and those holding less than 2 ha of land account for 35 percent. In many countries, up to 90 percent of forest enterprises are small or medium-sized; such enterprises generate more than half of forest-related employment.
- Smallholders, local communities and Indigenous Peoples own or manage at least 4.35 billion ha of forest and farmlands; according to one study, smallholders produce farm and forest products worth up to USD 869 billion to USD 1.29 trillion per year.

Local actors can be highly effective – and cost-effective – forest managers.

- There is evidence that, in general, smallholders with secure tenure tend to make longer-term investments in their lands and forests, compared with those with no or short-term security.
- Studies show that 91 percent of all indigenous and community lands are in good or moderate ecological condition, pointing to their potential for cost-effectively reducing

deforestation and improving forests. For example, securing indigenous lands in some countries in Latin America would cost less than 1 percent of potential revenues from carbon storage alone.

Customary forest rights are increasingly recognized in statutory laws, although progress has not been uniform.

- The devolution of rights on public lands in many countries has increased the ability of smallholders, local communities and Indigenous Peoples to sustainably harvest high-value forest resources and derive income from ecosystem services, REDD+ and carbon credits. There was a global slowdown in tenure recognition for Indigenous Peoples, local communities and rural women between 2002 and 2017, however.
- Accelerating the formalization of customary and collective rights is crucial for protecting remaining forests and mobilizing resources for recovery. Some governments are pursuing policies to, for example, recognize customary lands without the need for titling and simplify land registration processes. A range of new low-cost technologies can also help secure community tenure through participatory processes.
- For most smallholders, tree (and carbon) rights are even more uncertain than land rights. Although this is changing, most countries that give farmers tree rights also heavily regulate tree use and management on private lands. Governments can promote restoration and agroforestry by, for example, offering secure, long-term rights to trees and tree products in exchange for the adoption of good management practices, such as sustainable agroforestry.

Local producer organizations and other relevant groups can help enable the three forest pathways but require support.

- More than 8.5 million social cooperation groups exist worldwide, and their influence in forestry is growing. The three types are: (1) groups such as community forest user groups formed to protect user rights, enable and promote sustainable production and value-adding, and provide business and financial services to members; (2) groups associated with social movements, such as to advance legal reforms to strengthen rights and remove regulatory barriers; and (3) groups aimed at inclusively addressing deforestation and forest degradation as part of jurisdictional approaches.
- Existing financial programmes and policies to support such organizations provide insights into how this might be done elsewhere.

Increasing capacity and co-producing knowledge with smallholders, local communities and Indigenous Peoples would help scale up the three forest pathways.

- Capacity development in forestry has declined in many countries, but opportunities exist to reverse this trend. A starting point would be to reinvest in forestry and agroforestry extension programmes, such as through farmer and pastoralist field schools and learning-by-doing initiatives in community-based forestry. Identifying and capitalizing on diverse sources of knowledge and new technologies can facilitate innovative and inclusive solutions grounded in local systems.
- Supportive policies could be put in place to enable forestry capacity development based on partnerships and engagement between traditional knowledge-holders and service, training and educational organizations. A range of actions is available to ensure that efforts are inclusive of women and men, youth, Indigenous Peoples, the poor and the vulnerable.
- Mobilizing and investing in digital technologies and services can help accelerate change and the uptake of the three forest pathways. Increasing means exist for overcoming barriers to digital engagement, but there are significant limitations: about one-quarter of people in least-developed countries lack access to mobile broadband services and, in Africa, only about 6 percent of rural households have internet access. Nevertheless, information from public and private technical and extension services is increasingly available online and as apps on mobile devices, making them more inclusive.

Increasing internet access in rural areas could enable the rapid strengthening of local organizations and their work in supporting local green recovery and sustainable development.

6 – THE FOREST PATHWAYS – A MEANS FOR GREEN RECOVERY AND RESILIENT ECONOMIES?

Most countries have taken steps along the forest pathways, although few appear to have coherent policies to promote all three and enhance their complementarity.

- There is clear international momentum for the pathways, and the time is right for bold strategies to scale up the pathways in ways that are mutually reinforcing and build resilience.

The three forest pathways carry economic, social, political and environmental risks.

- For example, there is a risk that investors, including smallholders, will miss investing in more profitable ventures; conversely, the diversification offered by the forest pathways could increase the economic resilience of local actors. Another risk is that climate change could threaten the viability of restoration efforts, and adaptive management will be important to mitigate this.

Next steps could involve four possible actions:

1. directing funding for recovery towards long-term policies aimed at creating sustainable economies and green jobs and further mobilizing private sector investment;
2. empowering and incentivizing local actors to take a leading role in the forest pathways;
3. engaging in policy dialogue on sustainable forest use as a means for simultaneously achieving economic and environmental goals; and
4. maximizing synergies among the three forest pathways and between agricultural, forestry, environmental and other policies and minimizing trade-offs.

MONGOLIA
A member of the Khargistai-Bayanburd Forest User Group moving felled trees onto a vehicle.
©FAO/Sean Gallagher

CHAPTER 1
CAN FORESTS AND TREES PROVIDE MEANS FOR RECOVERY AND INCLUSIVE, RESILIENT AND SUSTAINABLE ECONOMIES?

HEADLINES

➔ **Humanity is facing multiple global threats.** These include a health pandemic and related economic hardships, food insecurity, poverty, climate change, conflicts, land and water degradation, and biodiversity loss.

➔ **The world needs solutions at scale that are cost-effective and equitable and can be implemented rapidly, and forests and trees have clear potential.** Societies could make better use of forests and trees to simultaneously conserve biodiversity, better provide for human well-being, and generate income, particularly for rural people.

➔ **Three forest-based pathways warrant close examination as means for tackling local to global challenges.** These are (1) halting deforestation and maintaining forests; (2) restoring degraded lands and expanding agroforestry; and (3) sustainably using forests and building green value chains.

The COVID-19 pandemic is a health crisis accompanied by an economic crisis threatening the lives, livelihoods, well-being and future of people worldwide. Its effects on jobs and incomes and consequences for health, hunger and poverty are of a severity and scale unseen for more than half a century. The pandemic poses formidable challenges for policymakers in governments and decision-makers in businesses who are required to mitigate impacts and keep societies, economies, communities and businesses afloat, including through fiscal stimuli to maintain jobs and income without destroying long-term economic and social stability and sustainability. At the same time, world leaders and societies are being challenged to find effective, cost-efficient and socially acceptable ways to address the twin threats of climate change and biodiversity loss. Moreover, the global population is projected to increase from 7.7 billion people in 2019 to 9.7 billion people in 2050, and the annual global consumption of natural resources such as biomass, fossil fuels, metals and minerals could more than double by 2060 – raising the prospect of further environmental damage caused by increased production, consumption and waste generation.

The confluence of planetary-scale crises poses a serious threat. It has sharply raised awareness of critical weaknesses and risks in societal and economic systems, including humanity's relationship with and impacts on nature. Forests have been hard-hit in recent decades by clearance and unsustainable practices, but they have also always been an important resource for human well-being and wealth creation. The world needs solutions at scale that are cost-effective, inclusive and equitable and can be implemented rapidly. The economic impacts of the COVID-19 pandemic and the need to respond in ways that support people and their livelihoods bring into stark focus the importance of balancing natural resource protection and use. Forestry – which yields a vast range of products and ecosystem services useful both for local communities and at a global scale – could play a key role in accelerating a transformation towards societies that simultaneously conserve nature, better provide for human well-being, and generate income, particularly for rural people. This is particularly pertinent at a time when government deficits are rising and economies, communities and families are struggling.

NORTH MACEDONIA
Aerial view of conifer and scrub forest.
©FAO

It is 50 years since the first global conference on the (human) environment in 1972 and 30 years since a common global perspective was set at the UN Conference on Environment and Development. It is also nearly seven years since the UN General Assembly agreed on the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs). Over this period, it has become increasingly clear that forests and trees have crucial roles to play in sustainable development, achieving the SDGs and keeping climate change within manageable boundaries.

This edition of *The State of the World's Forests* (SOFO 2022) presents three pathways that, especially if pursued simultaneously, could help address the crises facing the planet while also generating sustainable economic benefits. The pathways are:

1. halting deforestation and forest degradation as a crucial element for reversing the drivers of climate change, biodiversity loss, land degradation, desertification and threats to human health (**"halting deforestation and maintaining forests"** – also "halting deforestation");
2. restoring degraded forests and landscapes and putting more trees into agricultural settings as cost-effective means for improving natural assets and generating economic, social and environmental benefits **("restoring degraded lands and expanding agroforestry"** – also "restoration"); and
3. increasing sustainable forest use and building green value chains to help meet future demand for materials and ecosystem services and support greener and circular economies, particularly at the local level (**"sustainably using forests and building green value chains"** – also "sustainable use").

SOFO 2022 examines ways of integrating these pathways into existing and emerging policy and investment mechanisms, addresses the benefits and costs of the pathways, assesses the potential for additional finance for the pathways, and explores how best to enable adoption, where appropriate, by decision-makers on the ground.

Chapter 2 of SOFO 2022 reviews data on forests and trees as assets that provide societies with multiple benefits. It looks at who owns and manages these assets and how their benefits flow in practice, especially to local people; it also considers the impacts of the COVID-19 pandemic on forests and forest-dependent people. Chapter 3 scrutinizes the costs and potential benefits of the three mutually reinforcing forest pathways. Chapter 4 explores mechanisms for scaling up investment in the sector to the level needed to fuel this transformation. Chapter 5 examines the status of smallholders, local communities and Indigenous Peoples as forest and tree managers and innovators and the policy changes needed to help them drive transformation in the forest sector, including by supporting social cooperation organizations, women and youth. Chapter 6 outlines some initial next steps that policymakers could take in further exploring the potential of the three pathways. ■

THAILAND
A woman unloading mangrove logs that will be used for charcoal production.
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CHAPTER 2
FORESTS AND TREES PROVIDE VITAL GOODS AND ECOSYSTEM SERVICES BUT ARE UNDERVALUED IN ECONOMIC SYSTEMS

HEADLINES

➔ **Forests are resources of global significance.** They cover nearly one-third of the Earth's land surface and contain the majority of terrestrial biodiversity. The forest area continues to shrink, however, despite efforts to halt deforestation and restore degraded lands.

➔ **Forests are crucial for mitigating climate change.** They contain 662 billion tonnes of carbon, which is more than half the global carbon stock in soils and vegetation.

➔ **Societies benefit from and are highly dependent on forests.** More than half of world gross domestic product is estimated to depend significantly on ecosystem services. The forest sector contributes more than USD 1.52 trillion to world gross domestic product and employs 33 million people.

➔ **Many forest-proximate people obtain insufficient benefits from forests.** Seventy-five percent of all rural people live within 1 km of forest, but many have few rights to forests, with states owning nearly three-quarters (73 percent) of all forests. Eighty percent of the extreme poor live in rural areas.

➔ **The COVID-19 pandemic had a significant impact on forest value chains and trade in early 2020. Most sectors rebounded quickly, but the risk of future pandemics remains.** Forestry is well placed to play an important role in green recovery.

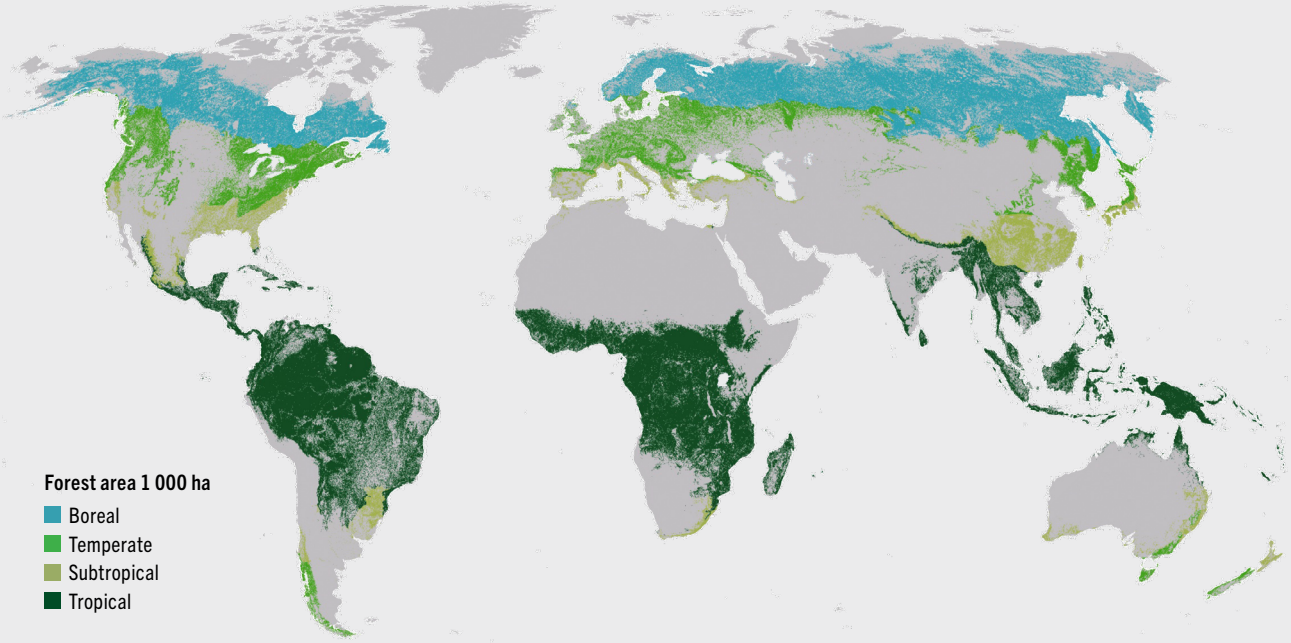
The world is at risk of large-scale and potentially irreversible environmental changes, with major threats related to climate, biodiversity, natural resources and human well-being. As the window for action narrows, and as population growth and aspirations place new demands on physical resources, it seems clear that natural ecosystems are vital assets that must be restored, maintained and sustainably managed. This chapter presents the most recent data on the status of, trends in, and value of global forest and tree resources as a baseline for designing cost-effective options and wide-impact pathways towards a healthy planet and sustainable and resilient societies.

2.1 DEFORESTATION AND FOREST DEGRADATION PERSIST

Forests cover nearly one-third of the Earth's land surface but the area is shrinking despite efforts to halt deforestation and restore degraded lands

Forests occur in the four major climatic domains (boreal, temperate, subtropical and tropical) (Figure 1). In total, they cover 4.06 billion ha (31 percent of the world's land surface), but this area is decreasing, particularly in the tropics. The FAO Global Forest Resources Assessment (FRA) 2020 estimated that 420 million ha of forest was deforested (converted to other land uses) between 1990 and 2020; although the rate declined over the period, deforestation was still estimated at 10 million ha per year in 2015–2020 (approximately 0.25 percent per year) (Box 1 discusses the definition of deforestation; Chapter 3.1 examines its drivers).[1] This deforestation was not fully matched by afforestation and natural forest expansion, estimated at about 5 million ha per year over the same period.

FIGURE 1 THE GLOBAL DISTRIBUTION OF FORESTS, BY CLIMATIC DOMAIN, 2020



SOURCE: FAO. 2020. *Global Forest Resources Assessment 2020 – Main report*. Rome. https://doi.org/10.4060/ca9825en

There are significant regional differences in the patterns of forest-area change: the highest net losses in 2010–2020 were in South America and Africa, while Europe and parts of Asia experienced net gains. The rate of net forest loss decreased in South America in 2010–2020 compared with the previous decade.[1]

Primary forests. Approximately one-third (34 percent) of the world's forests are primary (that is, consisting of native tree species and having no clearly visible indications of human activities and no significant disturbances in ecological processes). Primary forests have decreased by an estimated 47 million ha globally since 2000, with the rate of loss more than halving in 2010–2020 compared with the previous decade. Combined, three countries – Brazil, Canada and the Russian Federation – host more than half (61 percent) of the world's primary forests. Canada and the Russian Federation reported very low or no deforestation between 1990 and 2020; despite an overall reduction in deforestation, however, Brazil has experienced substantial forest loss since 1990, including of primary forests. Naturally regenerating forests (i.e. forests predominantly composed of trees established through natural regeneration, including primary forests) account for 93 percent of the world's forest area.[1]

Planted forests. Seven percent (294 million ha) of the forest area worldwide was composed of planted forests in 2020. Globally, the rate of increase in planted-forest area declined from 1.4 percent per year in 2010–2015 to just less than 1 percent per year in 2015–2020. South America had the highest rate of increase in 2010–2015; although the rate declined in 2015–2020, the region still had the highest rate of increase in relative terms in that period, followed by North and Central America.[1]

BOX 1 DEFINING AND MEASURING DEFORESTATION

According to the definition used in FAO's Global Forest Resources Assessment (FRA), deforestation is "the conversion of forest to other land use independently of whether human-induced or not".[2] That is, deforestation is essentially referring to a change in land use, not in tree cover. Defining deforestation thus implies a definition of forest, which, in the FRA, combines physical criteria (minimum thresholds of 10 percent canopy cover, 0.5 ha in area and 5 m in height) and a notion of the predominant land use, excluding tree-covered areas where the predominant use is agriculture or urban; hence, the definition excludes plantations of agricultural tree crops (such as oil-palm plantations and orchards) as well as urban parks but includes various types of planted forests (including rubber plantations).[3] Nevertheless, many technical and scientific studies do not use FAO's definition but rather equate deforestation with tree-cover loss without taking land-use criteria into account. This approximation is used in remote-sensing-based methodologies for two reasons – it considers all tree cover (including tree-covered areas not meeting FAO's forest definition); and it counts instances of non-permanent tree-cover loss (e.g. the clearfelling of a natural or planted forest that will later regrow, and the temporary consequences of a forest fire) as deforestation. When interpreting deforestation figures in different studies, therefore, users should be aware of the impacts of the definitions and tools used.

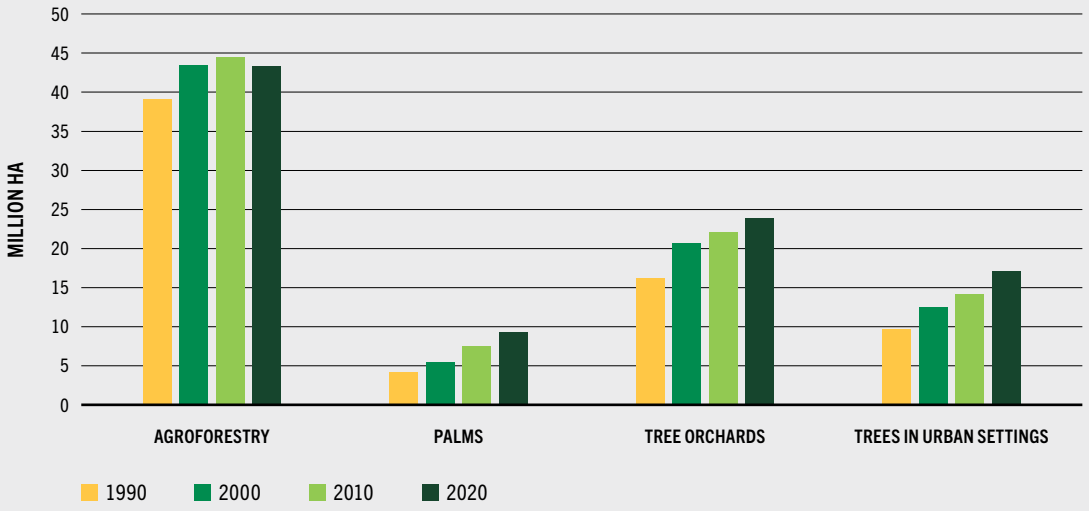
Plantation forests (an intensively managed subcategory of planted forests) covered about 131 million ha in 2020, which was 3 percent of the global forest area and 45 percent of the total area of planted forests. Asia accounted for more than half this plantation-forest area. Plantation forests in North and Central America are composed mostly of native species, and those in South America consist almost entirely of introduced species.[1]

Other wooded land. Worldwide, the area of other wooded land was estimated at 977 million ha in 2020, which was 7 percent of the total land area (and about one-quarter the area of the global forest area). Africa had the largest area of this category (446 million ha), followed by Asia (191 million ha), South America (147 million ha), Europe (100 million ha), North and Central America (90.5 million ha) and Oceania (2.47 million ha; note, however, that Australia did not report on its area of other wooded land for FRA 2020).

The area of other wooded land decreased by nearly 1 percent (about 9 million ha) between 2000 and 2020. Many countries face challenges in monitoring change in this land-use category, largely associated with difficulties in measuring tree-canopy cover in the range of 5–10 percent; thus, they lack reliable data on it.[4] Recent estimates based on FAO's latest remote sensing survey suggest that the global area of other wooded land may be significantly higher than reported to FRA 2020.[5]

Other land with tree cover. Other land with tree cover has four subcategories: 1) trees in urban settings; 2) tree orchards; 3) palms; and 4) agroforestry (Figure 2). The area of palms more than doubled between 1990 and 2020, from 4.2 million ha to 9.3 million ha, based on the 83 countries that reported. Seventy-one countries and territories worldwide reported a total area of 45.4 million ha of agroforestry in 2020, mostly in Asia (31.2 million ha) and Africa (12.8 million ha) (there was also an estimated 1.28 million ha of agroforestry in North and Central America). In the 54 countries and territories that reported trend data on agroforestry, the area of land subject to this use increased by 4.21 million ha between 1990 and 2020, to 43.3 million ha. Most of the increase was in Asia and Africa.[6] Note, however, that estimates based on FAO's latest remote sensing survey suggest that the global area of other land with tree cover may be significantly higher than reported to FRA 2020.

FIGURE 2 GLOBAL AREA OF OTHER LAND WITH TREE COVER, 1990–2020



SOURCE: FAO. 2020. *Global Forest Resources Assessment 2020 – Main report*. Rome. https://doi.org/10.4060/ca9825en

In many countries with low forest cover, trees outside forests constitute the main source of wood products and also non-wood forest products (NWFPs), even though the trees may be scattered.

Biodiversity. Forests harbour most of Earth's terrestrial biodiversity and its three components – ecosystem, species and genetic diversity. Trees are the foundations of forest ecosystems, and many of the world's 60 000 tree species[7] are also important components of woodlands and agricultural landscapes. Forests provide habitats for about 80 percent of amphibian species, 75 percent of bird species and 68 percent of mammal species.[8] About 60 percent of all vascular plants occur in tropical forests.[9] The genetic diversity of trees is being threatened and eroded by the loss of tree populations, unsustainable harvesting, overgrazing, climate change, fire and invasive species.[10] Projected declines in the diversity and abundance of many major pollinators pose a threat to food security, human health and the cultural fabric and livelihoods of millions of people, especially rural and indigenous communities.[11]

Forest degradation is difficult to quantify but is likely increasing

Human activities, severe climatic events, fire, pests, diseases and other environmental disturbances may degrade forests and thereby reduce the provision of forest goods and services, biodiversity values, productivity and health. Forest degradation may also negatively affect other land uses (e.g. by causing a loss of downstream water quality and affecting groundwater recharge) and cause the emission of greenhouse gases (GHGs). Despite its importance, a widely applied definition of forest degradation is unavailable, and data are scarce. For FRA 2020, 58 countries representing 38 percent of the global forest area reported that they monitored the area of degraded forest, but they used varying definitions of degraded forest and few applied quantitative criteria.[1]

Human-induced land degradation and desertification, water scarcity and climate change are increasing the levels of risk for agricultural production and ecosystem services. Converging evidence indicates that, as agriculture

intensifies, so too does the extent and severity of land degradation in terms of soil erosion, nutrient depletion and salinization.[12] Human-induced degradation affects 34 percent of agricultural land: one-fifth of human-induced degraded land is in sub-Saharan Africa, followed by Southern America at 17 percent; Northern America and South Asia contribute 11 percent to global degradation; and, in relative terms, South Asia is the most-affected region, with 41 percent of its area suffering from human-induced degradation.[13]

Climate change and human influence affect the dynamics of forest ecosystems and their resilience to invasive species and diseases – with potentially very large ecological and economic impacts. For example, estimates show that southern pine beetle-induced timber mortality in the southern United States of America caused losses to timber producers of about USD 1.2 billion between 1982 and 2010 (i.e. USD 43 million per year, on average).[14] The average annual damage caused by bark beetles in forests in parts of Europe (i.e. Belgium, Denmark, France, Germany, Luxemburg and the Netherlands) is projected to be almost six times higher in 2021–2030 than it was between 1971 and 2010.[15]

About one-third of global forest loss is fire-related

Forest fires (90 percent of which are caused by humans) can have wide-ranging negative impacts on ecosystems and serious implications for the achievement of many of the SDGs, including those related to biodiversity, water, health, life on land and climate. Fire affected approximately 98 million ha of forest globally in 2015 and damaged about 4 percent of the tropical forest area.[16] Recent research shows that 29–37 percent of global forest loss (measured as permanent and non-permanent tree-cover loss) in 2003–2018 was fire-related.[17] There are indications that the incidence and severity of fire are increasing. Australia, for example, suffered its worst fire season in history in 2019–2020, with an estimated 10.2 million ha burnt, including 8.19 million ha of native forest (the remainder comprising agricultural croplands and grasslands, forest plantations and other non-native forest, peri-urban lands, and native grasslands, heath and shrublands).[18]

Forests accumulated more carbon than they emitted in the last decade

Forests play an important role in the global carbon cycle, functioning both as a source of GHG emissions (through deforestation and degradation) and a sink (through carbon capture via photosynthesis and storage in biomass and soils). Forest carbon stock is the carbon contained in forests in four pools – living biomass, dead wood, litter and soil organic matter. Forests sequester carbon from the atmosphere during photosynthesis but can also release stored carbon, such as in the case of deforestation, fire and tree decay. Forest carbon stock, and changes in this, are important indicators of the role of forests in the global carbon cycle and of the quality of forest management.

The total carbon stock in forests was estimated at 662 Gt in 2020, at an average of 163 t per ha.[19] About 45 percent of the forest carbon stock in 2020 was in living biomass, 45 percent was in soil organic matter and 10 percent was in dead wood and litter.[20] The global forest carbon stock decreased between 1990 and 2020 but forest carbon stock per ha increased, likely partly due to improved forest management.[21]

Net emissions from land use, land-use change and forestry were 4.1 $GtCO_2$ per year, or about 10 percent of total anthropogenic CO_2 emissions, between 2011 and 2020.[22] The terrestrial sink (mostly forests) has been significantly larger than emissions from land-use change,[23] however, sequestering 11.4 $GtCO_2$ per year, which was as much as 29 percent of annual anthropogenic CO_2 emissions in 2011–2020.[24] Tropical and subtropical regions represent 78 percent of gross emissions and 54 percent of gross removals.[25]

Other impacts of forests on climate. Changes in forest cover and characteristics also influence climate in other ways. For example, they affect albedo (the extent to which solar radiation and therefore heat is reflected back to the atmosphere), the emission of water vapour into the atmosphere (through evapotranspiration), the height above the Earth's surface to which heat and water vapour are forced upward (by the "roughness" of tree canopies),

and the extent to which dust and smoke particles, pollen and microbes enter the atmosphere as aerosols (with their own effects on temperature). Trees also emit other chemicals that affect climate, such as biogenic volatile organic compounds.

The negative local and regional effects of forest and tree loss on temperature and rainfall can be substantial, especially in the tropics. Declines in rainfall linked to deforestation in the southern Brazilian Amazon could cause agricultural losses (e.g. declines in soybean and livestock yields) valued at more than USD 1 billion per year between now and 2050;[26] recent modelling also indicates that deforestation of remaining humid rainforests in Africa would likely dramatically affect rainfed agriculture across the continent, particularly maize-based cropping systems north of the equator.[27] The local to regional impacts of forests on climate can be important for reducing urban heat (primarily through transpiration, shading and albedo); for example, trees in urban settings have been shown to reduce land surface temperatures in Central Europe in summer and during heat extremes by as much as 12 °C.[28]

Land-use change has caused the emergence of more than 30 percent of new diseases since 1960

Forest loss has negative direct and indirect impacts on human health, although data are limited (comparative datasets do not exist at the global level) and the risks of emerging infectious diseases (EIDs) associated with forest ecosystems are poorly studied. Most research tends to focus on a few specific diseases (and known reservoirs or hosts) rather than attempting to fully understand all relevant host–pathogen–environment dynamics in an ecosystem. Nevertheless, the majority (60 percent) of EIDs are caused by pathogens that have a non-human animal source (i.e. are zoonotic), and nearly three-quarters (71.8 percent) of such zoonotic EIDs originate in wildlife.[29] Landscape change and biodiversity loss involve major shifts in the ecology of pathogens and the wildlife habitats or species they use as hosts and reservoirs, thus altering disease patterns. Moreover, such changes tend to put people physically in closer contact with pathogens, and the wildlife trade can bring pathogens into the human population. Land-use change (comprising deforestation, human settlement in primarily wildlife habitat, the spread of crop and livestock production, and urbanization) is a globally significant driver of pandemics; it is estimated to have caused the emergence of more than 30 percent of new diseases reported since 1960.[30]

Deforestation and forest fragmentation also bring people and livestock into closer contact with wildlife, increasing human–wildlife conflicts and the risk of disease transmission between them. Deforestation is an important factor in the spread of vector-borne diseases (i.e. diseases, such as malaria, that are transmitted by vector species between susceptible species).[31] A recent study found that 15 percent of about 250 analysed EIDs were linked to forests,[32] several of which (e.g. Ebola and human immunodeficiency virus infection/acquired immunodeficiency syndrome) are particularly harmful to human health and economies. Deforestation, particularly in tropical regions, has been associated with an increase in infectious diseases such as dengue fever, malaria and yellow fever.[33]

Ebola virus disease, which was first identified in humans in sub-Saharan Africa in 1976 and reportedly killed over 11 000 people across West Africa in an outbreak in 2014–2016, has been associated with rapid forest clearance: based on land-cover change and recent data on outbreaks, researchers found that an Ebola epidemic is more likely to occur in areas where forest cover has been fragmented by deforestation, typically within a time frame of two years after deforestation has occurred.[34,35] ■

2.2 NINETY-FIVE PERCENT OF RURAL PEOPLE GLOBALLY LIVE WITHIN 5 KM OF FOREST — GOVERNMENTS HOLD NEARLY THREE-QUARTERS OF FORESTS

According to a new study that combined data on tree cover and human population density to map the spatial relationship between people and forests on a global scale, 95 percent of all people outside urban areas – 4.17 billion people – lived within 5 km of a forest in 2019 and 75 percent – 3.27 billion people – lived within 1 km.[36] There is likely a high correlation between forest proximity and extreme poverty, given that 80 percent of the extreme poor live in rural areas.[37]

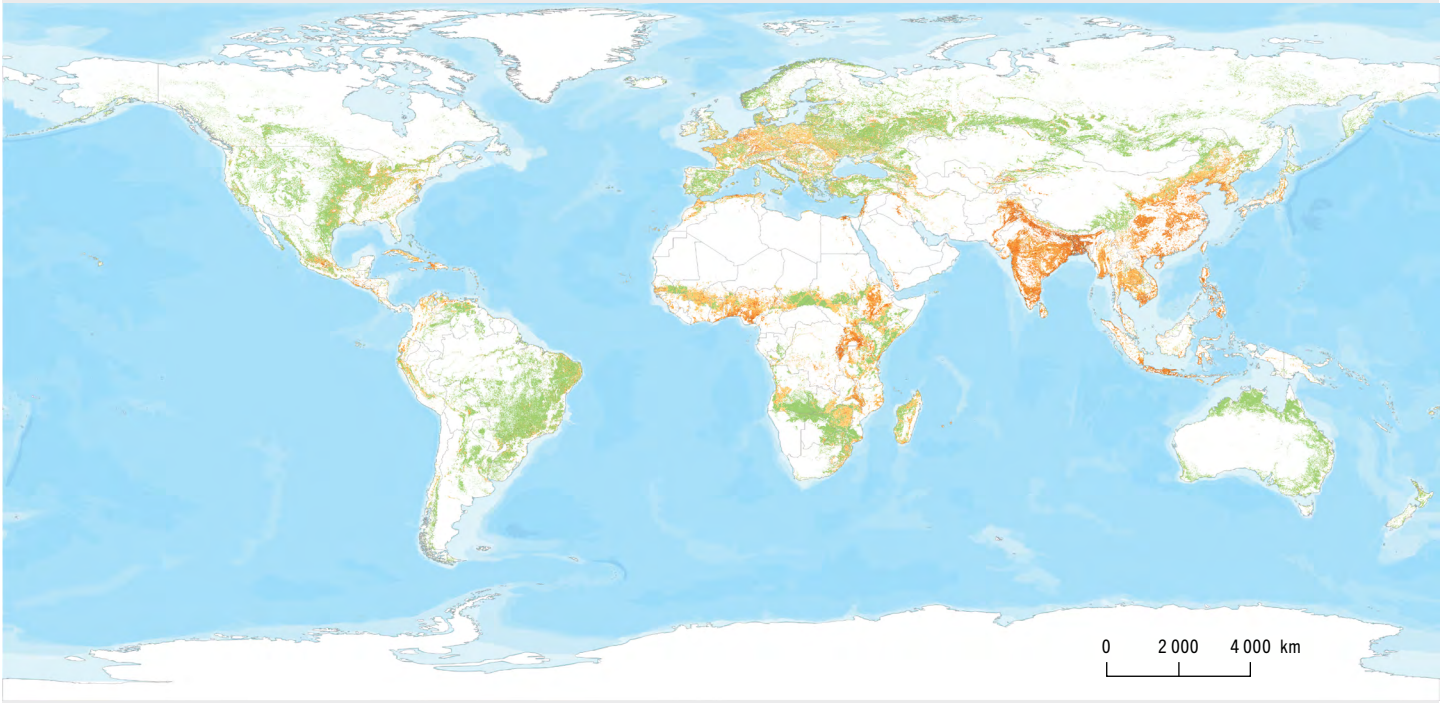
The majority of people living near trees outside forests on agricultural lands are in Africa and Asia (Figure 3). For example, a large-scale study of five countries in sub-Saharan Africa found that one-third of rural smallholder households grow trees, which contribute an estimated 17 percent of total annual gross income to these households.[38]

The livelihoods and well-being of people living near forests and trees can depend to a large extent on their rights to use these resources for their own benefit. According to FRA 2020, 73 percent of forests globally were owned publicly in 2015, 22 percent were under private ownership and 4 percent were categorized as unknown.[39] Public ownership was predominant in all regions, with differences among subregions: in Western and Central Africa, for example, 93 percent of forests were publicly owned and 2 percent were under private ownership; in Northern Africa, 73 percent were publicly owned and 27 percent were under private ownership; in Western and Central Asia, 99 percent were publicly owned and 1 percent were privately owned; and, in Central America, private ownership accounted for 51 percent of the forest area.[40] The proportion of management rights to publicly owned forest held by public administrations decreased globally from 96 percent in 1990 to 83 percent in 2015; the proportion held by business entities and institutions grew from 2 percent to 13 percent over the same period and the proportion held by local, tribal and indigenous communities increased from 1 percent to 2 percent.[41] In 2015, individuals accounted for 51 percent of the total area of privately owned forest in countries and territories reporting for FRA, local, tribal and indigenous communities for 29 percent and business entities and institutions for 20 percent.[42] Given the low coverage of the reporting, however, these figures present only a partial picture.

According to a Rights and Resources Initiative study (using a different methodology to FRA 2020) covering 58 countries (together representing nearly 92 percent of forests globally), Indigenous Peoples and local communities were legally recognized as owning at least 447 million ha (12 percent of the total forest area) in 2017; they also held legally designated rights (not counted as ownership) to more than 80 million ha (2 percent of the global forest area).[43] There was a global slowdown in tenure recognition for Indigenous Peoples, local communities and rural women between 2002 and 2017, according to the study.

Tenure and property rights reforms are expected to improve the well-being of those whose rights are formally recognized by enabling more secure access to resources, incentivizing long-term investment in forest resources, and, ultimately, alleviating poverty and inequality.[44,45,46] ■

FIGURE 3 DENSITY OF PEOPLE LIVING NEAR TREES ON AGRICULTURAL LAND, 2019



People per km²

≤ 1 ≤ 5 ≤ 50 ≤ 300 ≤ 1 000 ≤ 1 500 ≤ 1 501 No trees outside forests

NOTE: The map shows population density in 2019 within 1 km of agricultural land (i.e. croplands or potential grazing land) at least 1 ha in size where at least 10 percent tree cover (excluding forests) is present. Trees outside forests on urban land or non-urban/non-agricultural land are not depicted. The designations employed and the presentation of material on this map do not imply the expression of any opinion whatsoever on the part of FAO concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.
SOURCES: 100 m resolution global population density data obtained from: WorldPop. Undated. *Open spatial demographic data and research* [online]. [Cited 14 January 2022]. https://www.worldpop.org/; 100 m resolution global tree-cover fraction data obtained from Copernicus Global Land Cover: Buchhorn, M., Lesiv, M., Tsendbazar, N.-E., Herold, M., Bertels, L. & Smets, B. 2020. Copernicus Global Land Cover Layers—Collection 2. *Remote Sensing*, 12(6): 1044. https://doi.org/10.3390/rs12061044; 500 m resolution agricultural land-cover data obtained from MODIS Land Cover (MCD12Q1.006) to generate spatial overlays that identified population subsets near agricultural lands with trees outside forests in 2019: Friedl, M. & Sulla-Menashe, D. 2019. MCD12Q1 MODIS/Terra+Aqua Land Cover Type Yearly L3 Global 500m SIN Grid V006. NASA EOSDIS Land Processes DAAC. [Cited 19 January 2022]. https://lpdaac.usgs.gov/products/mcd12q1v006/. Google Earth Engine was used for the analysis.

2.3 SOCIETIES GAIN HUGE BENEFITS FROM FOREST ECOSYSTEM SERVICES – WHICH ACCOUNT FOR MORE THAN ONE-FIFTH OF THE TOTAL WEALTH IN LAND ASSETS

The estimated value of a subset of forest ecosystem services was USD 7.5 trillion in 2018, but forest wealth per capita has decreased in low- and middle-income countries

The wealth represented by certain forest ecosystem services (recreation and hunting, habitat, non-timber forest products and water services, excluding timber and carbon) is estimated to have increased from USD 5 trillion in 1995 to USD 7.5 trillion in 2018, which is 21 percent of the total wealth in land assets (comprising cropland, pastureland, forest timber, forest ecosystem services and protected areas).[47]

Forest timber wealth per capita declined between 1995 and 2005 (Figure 4), with reductions in all regions except Latin America and the Caribbean and South Asia (Figure 5); this measure increased between 2005 and 2018, however. Forest ecosystem services wealth per capita increased by about 15 percent between 1995 and 2018, with increases in all regions except sub-Saharan Africa.[48]

In low- and middle-income countries, forest wealth per capita (i.e. timber plus the three indicated forest ecosystem services per capita) decreased by 8 percent in 1995–2018 due to a combination of population growth and the loss of forest area. Also in low- and middle-income countries, wealth per capita in croplands and pasturelands increased by 9 percent between 1995 and 2018 due to area expansion and an increase in value per unit area. Many low-income countries, particularly in sub-Saharan Africa, experienced declines between 1995 and 2018 in their wealth per capita in land assets.[49]

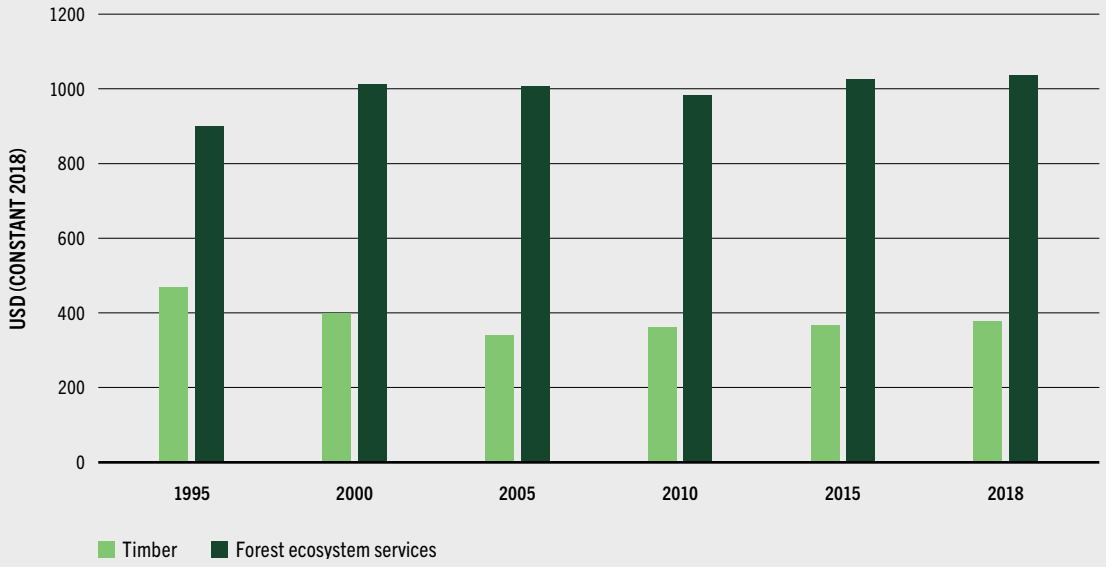
It is estimated that more than half of world gross domestic product (GDP) (USD 84.4 trillion in 2020) depends moderately (USD 31 trillion per year) or highly (USD 13 trillion per year) on ecosystem services – including but not limited to those provided by forests.[50] In addition, certain major sectors, such as travel and tourism, real estate, and retail, have hidden dependencies on ecosystem services through their supply chains.[51]

Attempts are underway to generate more reliable and comparable estimates of the economic value of nature

Timber, woodfuel and various forest fruits, resins and other non-wood products have markets of local, national and international significance, generating income, employment and production values that are captured in national registries and accounting systems. Despite recent efforts to broaden the international classification of forest products to encompass non-wood products,[52] however, reporting on these is still insufficient to enable robust quantifications of forest production. Accounting for the benefits to society provided by forest ecosystem services is even more challenging, given the general lack of markets for them (and those that do exist, such as for water and carbon, are at incipient stages).

The absence of natural asset stock such as forests in national asset/wealth accounting risks serious errors in policy decision-making, with a decline in natural assets likely to affect other assets in the longer term. It is unlikely that any national economy will be able to maintain current levels of wealth and well-being if climate change and natural-asset destruction continue at the current pace. Understanding the magnitude and importance of natural assets is essential for the design of policies and instruments aimed at achieving sustainable development and for identifying investment and income-generation opportunities and risks.

FIGURE 4 FOREST ECOSYSTEM SERVICES WEALTH PER CAPITA, 1995–2018



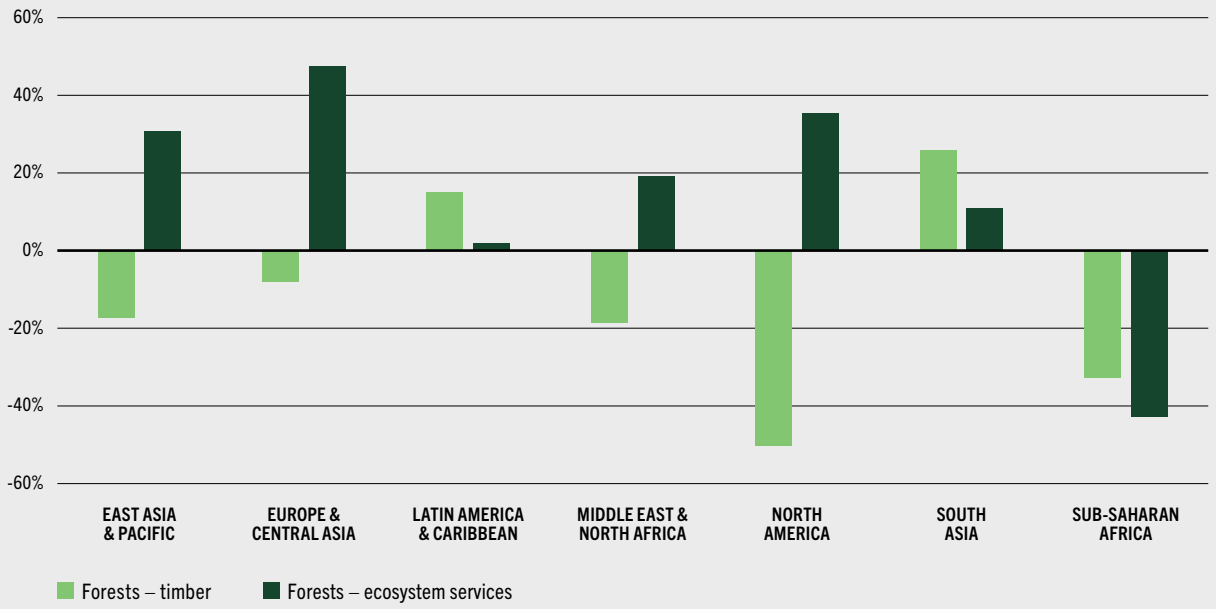
NOTE: The forest ecosystem services shown include only recreation, non-timber forest products and water.
SOURCE: Authors' elaboration based on World Bank. 2021. *The Changing Wealth of Nations 2021 – Managing assets for the future*. Washington, DC. https://doi.org/10.1596/978-1-4648-1590-4. License: Creative Commons Attribution CC BY 3.0 IGO

The adoption of the System of Environmental-Economic Accounting (SEEA) Ecosystem Accounting (EA) provides a means to increase tracking of the national value of nature and generate more reliable and comparable estimates. The SEEA-EA is a necessary complement to the System of National Accounts (Figure 6) – the latter summarizes national economic transactions and registers the relationship between the main national macro-economic aggregates, leading to the calculation of the most recognized economic measurement of the national economies, GDP, but it is limited to the accounting of products and services with significant market transactions. More concrete possibilities for trade, compensation and payments for all ecosystem services will likely emerge as countries advance in the use of the SEEA-EA.

FAO and the Foundation for Sustainable Development recently updated the Ecosystem Services Valuation Database (ESVD).[51] The aim was to produce value estimates for all forest ecosystem services in nine forest ecosystem types and mangroves (the latter defined in the SEEA as a transition ecosystem), as per The Economics of Ecosystems and Biodiversity and the SEEA classifications, and to increase the representation and geographic coverage of forest ecosystem services. By collating data from existing literature, the ESVD provides an overview of data availability on the values of ecosystem services from forest biomes. Comparing values across biome types is possible, with the qualification that information is incomplete and also more readily available for some biomes than others.

The ESVD presents mean values for ecosystem services by forest ecosystem type and indicates the magnitude of values and the coverage of the available data. There is considerable variation in estimates of ecosystem services across forest types, with very high values for some ecosystem services. For example, mangroves have high mean values for the provision of food (by supporting adjacent fisheries) and the

FIGURE 5 PERCENT CHANGE IN FOREST ECOSYSTEM SERVICES AND TIMBER WEALTH PER CAPITA, BY REGION, 1995–2018



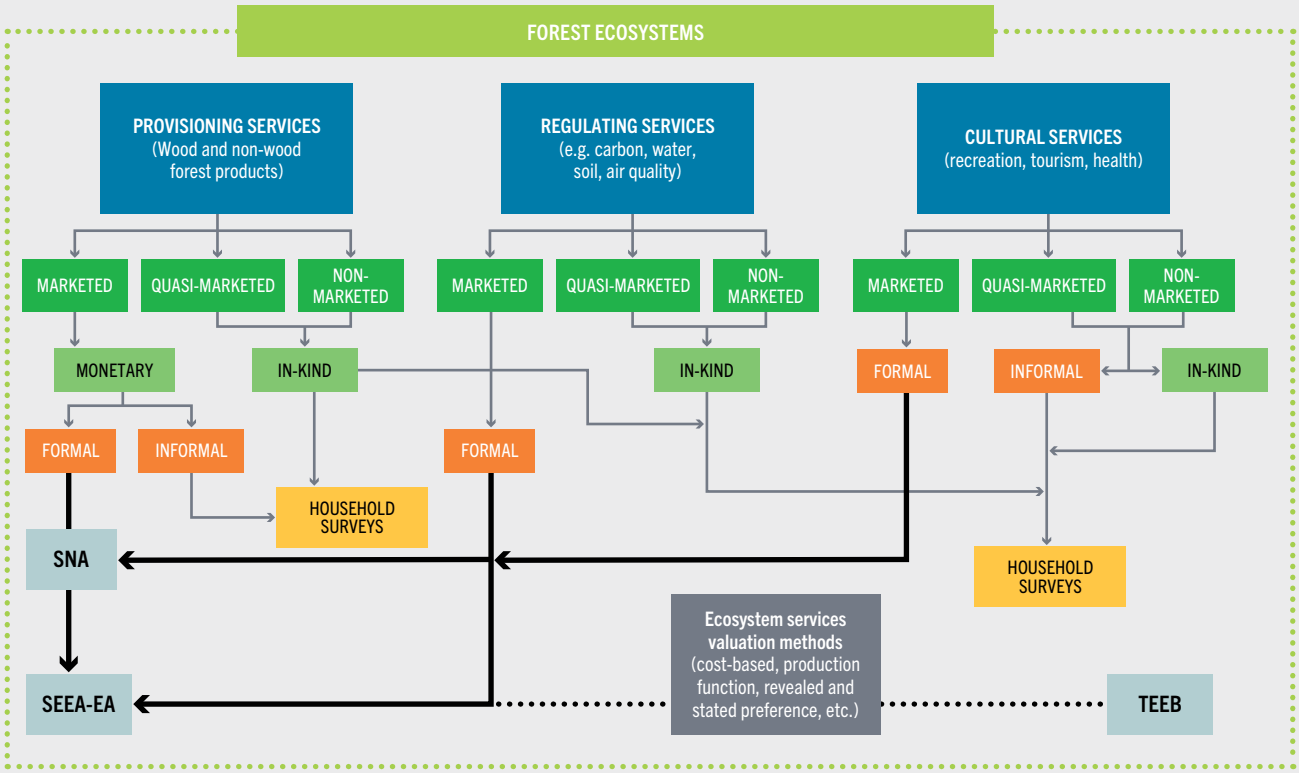
NOTE: The forest ecosystem services shown include only recreation, non-timber forest products and water.
SOURCE: Based on World Bank. 2021. *The Changing Wealth of Nations 2021 – Managing assets for the future*. Washington, DC. https://doi.org/10.1596/978-1-4648-1590-4. License: Creative Commons Attribution CC BY 3.0 IGO

moderation of extreme events (by mitigating coastal flooding). Urban parks and forests have high mean values for air-quality regulation and recreation, with a total value of just over Int$ 400 000[a] per ha per year.[53] National parks and protected areas generate considerable economic opportunities, as shown by recent growth in nature-based tourism (Box 2).

The values presented in the ESVD show that diverse combinations of forest ecosystem services can support many strategies for a resilient and more equitable planet. For example, based on the information available, tropical forests are equally valued for their provisioning and regulating ecosystem services (at 47.3 percent and 49.3 percent of the total value of ecosystem services for these forests, respectively). In contrast, temperate forests are equally valued for their regulating and cultural values (42.6 percent and 44 percent, respectively), and high mountain forests are overwhelmingly recognized for their regulating services, which account for about 87 percent of their attributed value.[54] ■

a International dollar (Int$) is a hypothetical unit of currency that has the same purchasing power parity that the United States dollar had in the United States of America at a given point in time. It is used mainly in economics and financial statistics for various purposes, most notably to determine and compare the purchasing power parity and GDP of various countries and markets. Source: Anonymous. 2022. International dollar [online]. Wikipedia [Cited 10 January 2022]. https://en.wikipedia.org/w/index.php?title=International_dollar&oldid=1063679744

FIGURE 6 THE RELATIONSHIP BETWEEN THE SYSTEM OF NATIONAL ACCOUNTS AND THE SYSTEM OF ENVIRONMENTAL-ECONOMIC ACCOUNTING – ECOSYSTEM ACCOUNTING IN THE VALUING OF FOREST ECOSYSTEM SERVICES



NOTE: NWFPs = non-wood forest products; SEEA-EA =System of Environmental-Economic Accounting – Ecosystem Accounting; SNA = System of National Accounts; TEEB = The Economics of Ecosystems and Biodiversity.
SOURCE: FAO.

BOX 2 THE ECONOMIC IMPORTANCE OF NATURE-BASED TOURISM

Before the COVID-19 pandemic, protected areas globally received roughly 8 billion nature-based tourism visits annually, generating about USD 600 billion per year in direct in-country expenditure; in addition, the "consumer surplus" (which measures the economic value of the environmental benefit to the visitor) was estimated at USD 250 billion per year.[55] In Finland, data on national park visitations have been collected systematically for 20 years, and the impacts of revenue and employment on local economies have been assessed since 2009. The data show that local economic benefits are considerable: the total impact of all 40 national parks in Finland on income and employment in 2019 was estimated at EUR 219 million and about 1 726 jobs (full-time equivalent). The biggest local economic impacts were in tourism centres, where visitors stay longer and where there is a good supply of tourism services. According to Metsähallitus, which manages national parks in Finland, the local benefits are tenfold compared with public investment in the areas.

SOURCE: M. Kniivilä and L. Tyrväinen, Natural Resources Institute Finland, personal communication, October 2021.

2.4 THE FORMAL FOREST SECTOR CONTRIBUTES MORE THAN USD 1.5 TRILLION TO NATIONAL ECONOMIES GLOBALLY

Forest product production and trade statistics focus on wood-based goods, historically the main products derived from forests and for which established markets exist. For many forest owners and managers, wood products are by far the most important source of income and employment in forestry and thus are playing a major role in rural recovery and development.

Analysis of the System of National Accounts offers a sound basis for harnessing the potential of sustainable forestry and forest provisioning functions. Accounts that permit the precise isolation of forest-related production are those referring to the wood-based industry (hereafter referred to as the forest sector[b]), comprising the categories "harvesting and logging"; "solid wood products" and "pulp and paper". Wood furniture and wood energy are accounted for in the System of National Accounts under furniture manufacturing and energy, respectively, and can be disaggregated. Data for wood energy still tend to be underreported and unreliable, although an exception is the production and trade of wood pellets, which is a relatively well-documented product that is commanding an increasing share of wood-based energy in total final energy consumption.

The total contribution of the (formal) forest sector to the global economy increased by 17 percent (nominal) between 2011 and 2015.[56] It directly contributed more than USD 663 billion to world GDP in 2015.[57] Taking into account the total economic effects (i.e. direct, indirect and induced economic contributions), including demand on other sectors and expenditure on labour income, the forest sector contributed more than USD 1.52 trillion to national economies in 2015 (up by 17 percent over 2011) (Table 1).[58] The pulp-and-paper sector was responsible for the highest direct generation of value added, at 31 percent, followed by forestry and logging and solid wood products (about 25 percent each of total sector value added). Furniture manufacturing contributed 19.6 percent. Asia (especially East Asia) dominates value-adding in the forest sector for all subsectors, contributing more than half the value added in all subsectors except furniture manufacturing.

These estimates are calculated using model data from 62 countries, which account for 70 percent of the world's total forest area and, in 2015, contributed 94 percent to global GDP and produced 93 percent of the total global industrial roundwood (IRW) as well as 94 percent of sawnwood, 97 percent of wood-based panels and 98 percent of paper and paperboard.[59] In addition, a set of econometric models[c] was used to estimate the economic multipliers of forest subsectors in countries without data. The results are helpful for the comparative analysis of the forest sector in national economies, but the national and global aggregates are underestimated due to the high informality of the sector, especially for non-exporting segments, and the weak reporting of forest-sector statistics, particularly in Africa. The lack of consistent data for sub-Saharan Africa downplays the economic role of the sector in that important producer region.

Wood products commanded about 2.3 percent of the value of global exports and imports in 2020. IRW removals amounted to 2.07 billion m^3 in 2018 and dropped to 2.02 billion m^3 in 2019 and to 1.98 billion m^3 in 2020, the latter fall likely influenced by the impacts of the COVID-19 pandemic.[60]

b Note, however, that the data presented here do not encompass all forest-related economic activity. For example, economic data on NWFPs tend to be included under agriculture, and wood-energy feedstock (such as wood pellets) and other bioenergy products (such as charcoal and fuelwood) are also accounted for elsewhere.

c The IMPLAN ("impact analysis for planning") system was used to generate data. The methodology is described in: Li, Y., Mei, B. & Linhares-Juvenal, T. 2019. The economic contribution of the world's forest sector. *Forest Policy and Economics*, 100: 236–253. https://doi.org/10.1016/j.forpol.2019.01.004

TABLE 1 ESTIMATED DIRECT AND TOTAL ECONOMIC CONTRIBUTION OF THE WORLD'S FOREST SECTOR TO GROSS DOMESTIC PRODUCT, BY SUBSECTOR, 2015

Region/ subregion	Forestry and logging		Solid wood products		Pulp and paper products		Furniture manufacturing		Total	
	Economic contribution									
	Direct	Total	Direct	Total	Direct	Total	Direct	Total	Direct	Total
	(USD million)									
Africa	13 457	45 301	2 170	7 007	2 651	8 725	4 191	11 598	22 468	48 296
Americas	39 679	92 050	18 398	55 038	31 702	90 184	15 413	39 454	105 192	257 275
Latin America and Caribbean	10 322	20 417	6 996	18 473	19 875	56 740	8 834	23 089	46 027	101 540
North America	29 356	71 632	11 402	36 565	11 827	33 445	6 579	16 365	59 165	155 735
Asia	81 474	126 558	88 984	364 562	108 045	373 477	59 452	181 749	337 955	765 307
Europe	30 505	59 534	47 188	132 381	58 741	158 485	48 818	112 529	185 252	423 109
Oceania	2 365	6 012	3 742	15 248	2 636	9 267	1 454	4 686	10 197	28 969
Grand total	167 480	329 455	160 482	574 236	203 775	640 139	129 328	350 016	661 064	1 522 957

NOTE: "Direct" shows economic contribution effects in the forest subsectors. "Total" includes direct, indirect and induced effects on value added. The direct effects across subsectors are additive but the total effects are not. For example, a portion of the indirect effects for furniture manufacturing is already included in the direct effects for forestry and logging. Summing the indirect and induced effects of subsectors would result in double counting.
SOURCE: Li, Y., Mei, B., Linhares-Juvenal, T. & Formenton Cardoso, N. 2022. *Forest sector contributions to the national economies in 2015 – The direct, indirect and induced effects on value-added, employment and labour income.* Rome, FAO.

The forest sector accounts for about 1 percent of global employment

The employment and income generated by the forest sector is a key issue for policymakers looking at ways to support recovery from the COVID-19 pandemic. Worldwide, more than 19.2 million people were estimated to have been directly employed in the formal forest sector in 2015,[59] with the four subsectors (forestry and logging, solid wood products, pulp and paper, and furniture manufacturing) contributing roughly similar quantities of jobs. More than half the formal jobs worldwide were in Asia, especially East Asia. The estimated combined direct contribution of the formal and informal forest sector to employment in 2017–2019 was 33.3 million jobs (based on 185 countries representing 99 percent of the global forest area; data exclude furniture manufacture) (Table 2).[61] This comprises about 1 percent of total employment globally for all economic activities. In 2017–2019, the majority of people in all regions (comprising 58 percent of total forest-sector employment) were employed in the manufacture of wood and wood products.

The forestry and logging subsector also played an important role in employment, especially in Africa, where it accounted for 42 percent of total forest-related employment.

For the formal sector only, estimates of the employment economic multiplier indicate that, for every 100 jobs in the sector in 2015, 73 additional jobs were supported (on average) in the national economy. These comprised 39 jobs in supplying sectors through backward linkages and 34 jobs in other sectors due to spending on goods and services by employees in the forest sector and its suppliers.[59]

The economic multipliers vary by subsector. In general, the processing subsectors (i.e. solid wood products, pulp and paper, and furniture manufacturing) tend to have higher multipliers in value added and employment than the forestry and logging subsector. Thus, having domestic wood-based manufacturing industries not only increases value added and creates employment in the forest sector, it also generates more value added and supports jobs in other sectors through indirect and induced effects.

TABLE 2 TOTAL DIRECT FORMAL AND INFORMAL EMPLOYMENT IN THE FOREST SECTOR, BY REGION AND SUBSECTOR, 2011–2013 AND 2017–2019

Region	No. of countries	Forestry and logging		Manufacture of wood and products of wood (solid wood products)		Pulp and paper manufacture		Total	
		(1 000 employed persons)							
		2011–2013	2017–2019	2011–2013	2017–2019	2011–2013	2017–2019	2011–2013	2017–2019
Africa	54	1 928.3	1 972.7	1 866.2	2 361.4	316.9	418.2	4 111.4	4 752.3
Americas	33	819.5	842.1	1 445	1 291.7	637.2	689.4	2 901.7	2 823.2
Asia	48	5 924	4 199.7	18 145	14 104.1	4 828.7	3 759.5	28 897.7	22 063.3
Europe	39	872.2	965.3	1 670.7	1 557.9	882.1	961.6	3 425	3 484.8
Oceania	11	64.6	77.7	73.4	85.2	27.1	25.2	165.1	188.1
Global	**185**	**9 608.6**	**8 057.5**	**23 200.3**	**19 400.3**	**6 692**	**5 853.9**	**39 500.9**	**33 311.7**

NOTE: These estimates are based on data on employment in the forest sector in the International Labour Organization's microdata repository and modelled estimates derived from the agriculture and manufacturing sectors to fill the gaps for countries without available data. Seventy-eight countries reported data related to the forest sector for at least one subsector in the microdata repository. For countries with missing data, estimates are based on regional coefficients and employment figures from the International Labour Organization's modelled estimates in the broad sectors of agriculture and manufacturing. Note that the manufacture of furniture is not included in these data.
SOURCE: Lippe, R.S., Cui, S. & Schweinle, J. Forthcoming. *Contribution of the forest sector to total employment in national economies*. FAO.

Informal employment (included in Table 2) is important in the forest-sector labour market. FAO estimates that, in 56 countries for which data were available, 7.7 million persons were employed informally in 2017–2019, which was 70 percent of the total forest-sector-related employment in those countries. The share of informal employment can be as high as 80 percent of total forest-sector-related employment in Asia and Oceania and 90 percent in Africa.[61]

An estimated 3.2 million women were employed in the forest sector in 68 countries for which data were available in 2017–2019, which was 23 percent of total forest-sector-related employment in those countries. Fewer women than men are employed in the forest sector in most countries, with a participation rate of 4–49 percent of total forest-related employment.[62] Nevertheless, the share of female employment in the sector is higher than that of men in some countries, particularly in Africa. Most female employment in the forest sector is informal and is often related to the gathering and production of woodfuel and NWFPs (and may be underestimated in the figures above).

The forest sector has been resilient in the face of the COVID-19 pandemic, but there have been significant impacts on woodfuel consumption

The COVID-19 pandemic caused a decline of 3.5 percent in the global economy in 2020[63] and is estimated to have pushed 124 million people into extreme poverty (i.e. people living on less than USD 1.90 a day).[64] There is no empirical evidence to support negative or positive effects of the pandemic on deforestation and forest degradation – even though deforestation increased in 2020, it is not possible to attribute this to the COVID-19 pandemic.[65] Nevertheless, forests face additional pressure due to the increased number of people living in poverty and the greater constraints faced by informal producers and small and medium-sized enterprises. Wood product markets have shown resilience in the face of the pandemic (Box 3).

Market information from 2020 has not led to strong changes in projections for wood products to 2050. The Global Forest Products Model

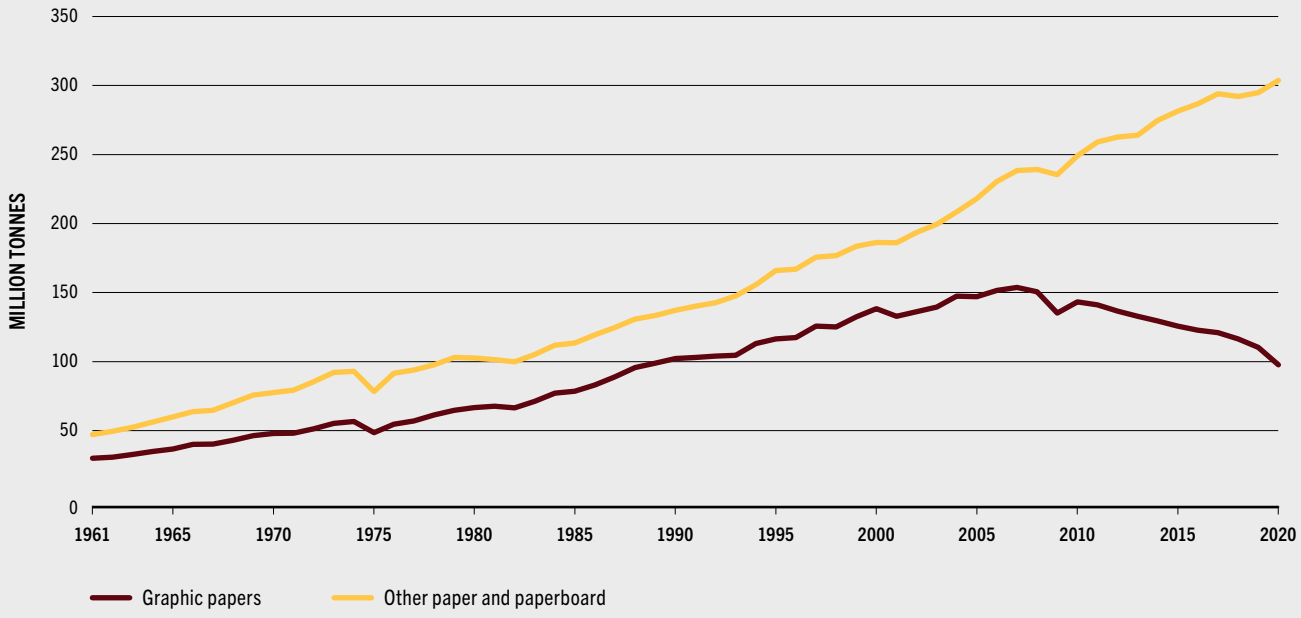
BOX 3 THE IMPACT OF THE COVID-19 PANDEMIC ON WOOD PRODUCTION AND TRADE

The COVID-19 pandemic appears to have had differential impacts on certain segments of the paper and paper products industry (Figure 7). The production of graphic papers, comprising newsprint and printing and writing papers, which has declined by 2–3 percent per year since 2007, dropped by 11.8 percent in 2020; global imports and exports also fell (by 13.6 percent and 15.9 percent, respectively). The steep drops in 2020 coincided with a spike in online activities precipitated by the pandemic, including business meetings, schooling and news consumption, thus reducing demand for printed paper.

In contrast, the production of other paper and paperboard (including packaging paper and paperboard and household and sanitary papers) grew by 3 percent in 2020, to 304 million tonnes. The increase was likely due to pandemic-induced online shopping, combined with an increase in the use of sanitary-paper products in hospitals.

Overall, there was a 5.1 percent reduction in wood product exports in 2020 and a 7 percent drop in imports, but the trade fluctuated over the year; a dramatic decline in the second quarter of 2020 was followed by a steep recovery.[66,67]

FIGURE 7 TRENDS IN THE PRODUCTION OF TWO MAIN TYPES OF PAPER PRODUCT, 1961–2020



SOURCE: FAO. Undated. *FAOSTAT* [online]. [Cited 19 August 2021]. https://www.fao.org/faostat/en/#data/FO

(GFPM)[d] projects an increase in the global production of IRW of 28 percent between 2020 and 2050, to 2.5 billion m^3. The main producers are projected to be Europe (32 percent of total IRW production), North America (25 percent) and East Asia (16 percent). North America, Latin America and the Caribbean and Oceania are projected to be net exporters, supplying regions such as East, Central, South and West Asia, North Africa and Europe.[68] These estimates do not take the COVID-19 pandemic into account, but a GFPM simulation run in May 2021 indicated a possible long-term impact of the pandemic to 2050 for

d The GFPM, parametrized in 2017–2019, draws on the FAO Yearbook of Forest Products until 2019, FRA 2020 and the most recent population and GDP forecasts provided by the Shared Socioeconomic Pathways Database of the International Institute for Applied Systems Analysis.

woodfuel consumption (an increase of 200 million m^3 compared with a scenario that does not take the pandemic into account) and almost no impact on long-term IRW production.[69]

Early evidence is available on the impacts of the COVID-19 pandemic on patterns and quantities of woodfuel production through case studies. For example, an assessment of the impacts of the pandemic in Kenya found that one-quarter of informal urban settlement households using liquefied petroleum gas before the pandemic switched their cooking fuel to wood or kerosene during a pandemic-related lockdown.[70] Future projections based on observed trends suggest that the number of people in sub-Saharan Africa relying on polluting fuels – i.e. unprocessed biomass (wood, crop residues and dung), charcoal, coal and kerosene – is likely to exceed 1 billion by 2025.[71] ■

2.5 WOOD ENERGY AND NON-WOOD FOREST PRODUCTS PLAY MAJOR ROLES IN THE MAJORITY OF RURAL HOUSEHOLDS

About 2.6 billion people rely on wood and other traditional fuels for household cooking

Woodfuel is a potentially renewable and carbon-neutral source of energy, and it undoubtedly has an important role to play in meeting future energy needs. But woodfuel also has significant negative impacts, especially in developing countries. Wood is an affordable fuel for those who lack access to other energy sources, but it takes time to collect and therefore often involves a tremendous opportunity cost, particularly for women. The extensive use of traditional woodfuel is a significant contributor to household air pollution, which is the third leading risk factor of global disease burden worldwide[72] and is responsible for an estimated 1.63 million–3.12 million premature deaths per year.[73] Woodfuel consumption could also pose a threat to the world's forests as a potential driver of deforestation and degradation.[74] One-third of the global population (about 2.6 billion people) relied on traditional fuels such as wood, charcoal and agricultural residues for household cooking in 2019; biomass and charcoal combined accounted for about 88 percent of the traditional cooking fuels used in low- and middle-income countries in that year.[75] If countries adopt only presently stated policies, nearly one-third of the global population will still not have transitioned to clean energy for cooking by 2030 and so will have to rely on the traditional use of woodfuel and other types of biomass energy.[76] Reliance on woodfuel is highest in Africa (63 percent of households – more than 90 percent of all wood cut in Africa is used as woodfuel[77]), followed by Asia and Oceania (38 percent) and Latin America and the Caribbean (15 percent).[78]

Due to the considerable reach of woodfuel in various sectors and in so many people's lives, accurate data are essential for better understanding trends and informing policymakers. The production and trade of wood pellets, which are relatively well documented, are associated with an increasing share of wood-based energy in total final energy consumption. Data on the informal collection of wood for use as fuel and on illegal charcoal production are sparse, however. A comparison between existing FAOSTAT data and data obtained from a systematic country-by-country search for 145 countries suggests that per capita woodfuel production in Africa and Asia will be revised upwards in future modelling.

At least 3.5 billion people use non-wood forest products

The subsistence use of forests and woodlands and their associated biodiversity can be more significant for local health, food, livelihoods and cultures than products that are traded. Estimates based on recent empirical studies of the number of users of non-timber forest products (defined as wild native or non-native

biological organisms and materials, other than high-value timber, collected from landscapes and habitats) put the lowest and median values at 3.5 billion and 5.76 billion people, respectively.[79] In Europe, the value of wild-collected forest products (including formally and informally marketed and self-consumed products) is estimated at EUR 23.3 billion per year, which is 71 percent of the value of annual roundwood production.[80]

Some NWFPs are driving multimillion and even multibillion-dollar industries associated with cosmetics, food, and health and well-being but may be invisible in national accounts because they are in categories encompassing both collected and cultivated volumes. For example, FAOSTAT[81] reports production and trade for Brazil nut (from the tree *Bertholletia excelsa*), which grows across the Amazon Basin and is harvested in the wild mainly in three countries: Bolivia (Plurinational State of), Brazil and Peru. The export value of Brazil nuts amounted to USD 373 million globally in 2019. FAOSTAT also contains data on the production and trade of shea nuts (used to produce shea butter) produced from *Vitellaria paradoxa*, a tree species with a wide range stretching from Senegal to Uganda. It is presumed that the majority of shea nuts used to make shea butter are collected in the wild. Six West African countries reported a total of 14 million tonnes of shea nut exports in 2007–2017, but the actual trade volume could be higher because other countries export shea nuts under more generic trade codes. An estimated 60–90 percent of internationally traded medicinal plant species are wild-collected.[82]

Forest wildlife plays an important role in food security, particularly in remote towns in the tropics and subtropics. The consumption of wild meat is estimated at 5 million tonnes per year in the Congo Basin and 1.3 million tonnes in the Amazon Basin,[83] providing an average of 60–80 percent of daily protein needs.[84] In Venezuela (Bolivarian Republic of), a 2012 study found that hunting fulfilled mainly subsistence purposes in indigenous communities, contributing 40–100 percent of the meat consumed.[85]

Wild animal- and plant-based foods can improve the quality of diets of those who consume them and provide income for those who sell or trade them. There are various reasons why the production of such wild food is challenging to measure, such as a lack of standard units, seasonal differences in collection patterns, and large numbers of species. Improving data on wild-food collection and consumption would increase understanding of the role of forests in sustainable dietary diversity and food security.

In many tropical countries, forest-adjacent people earn about one-quarter of their income from forests

Forests and tree-based systems can make both direct and indirect contributions to employment and income and alleviate the impacts of external shocks.[86] In 24 surveyed tropical and subtropical countries in sub-Saharan Africa, Asia and Latin America, forests contribute 20–25 percent of household income for forest-adjacent communities, a figure on par with the contribution of agriculture.[87] A global comparative analysis found that 77 percent of surveyed rural households engaged in wild-food collection.[88] In northeast India, more than 160 species of wild plants and fungi in local markets – most of them harvested in forests and woodlands – contribute up to 75 percent of the total income of some households and play an integral role in livelihood security.[89] Around Mount Cameroon in Cameroon, wild collections of forest products, mainly for food, contribute around 41 percent to local livelihoods, and native species contribute 45 percent, with households from all economic brackets participating in these activities.[90]

Forests and trees are significant to the spiritual and cultural values and traditions of many communities – especially Indigenous Peoples – and individuals.[91] These non-material factors are difficult to quantify but are clearly important for human well-being.

Forests and trees are sources of food, fodder, fuel and other products that can be harvested in otherwise difficult times and consumed at home or sold, helping to smooth consumption and income across seasons and years and thereby mitigating the risk that the poor will sink deeper into poverty and the non-poor will become

impoverished. The role of forests is especially important for the rural poor, who often lack access to other forms of insurance and social protection and who rely on livelihoods that are subject to external shocks such as crop-raiding by wildlife and variable weather.[92] Risk management is becoming more important in light of climate change and other global shocks such as the COVID-19 pandemic. More generally, the continued existence and health of forests and other tree-based systems is crucial for building resilience and retaining future options to support human well-being.

The evidence that forests and other tree-based systems support poor people to improve their well-being and mitigate risks is well established, but their role in helping people move permanently out of poverty is much less well documented. The full capitalization of this role is limited for the poor by difficulties in accessing credit, transport, markets, social protection and other public services, and by other barriers,[93,94] such as a lack of tenure. Access to new technologies can make a difference: for example, the adoption of improved shea butter processing technology has enabled rural women in Ghana to increase their household incomes.[95]

Even though woodfuel and NWFPs play crucial roles in supporting livelihoods, particularly for food security, data on these roles are weak and their value is best captured by household surveys and valuation techniques. National socio-economic surveys in forestry[96] have been implemented in Armenia, Georgia, Liberia, Sao Tome and Principe, and Turkey. In Turkey, about 50 percent of surveyed forest villagers collected non-wood plant products like rosehip, pinecones and mushrooms and about 44 percent collected medicinal or aromatic plants such as thyme and sage. In Liberia, a survey found that, in a 12-month period, 70 percent of households collected forest products for consumption or income (Box 4). In Georgia, woodfuel was used for cooking by 68 percent of households, for heating by 80 percent and to boil water by 56 percent. In Sao Tome and Principe, households were found to use forest or other wild products to cope with food needs during food-insecure months: more than 90 percent reported that such products were important or very important in their coping strategies, and 75 percent of this subset relied mainly on forest products to overcome their lack of food. A survey in Bangladesh found that nearly two-thirds of households collected forest products (Box 5).

Building on biophysical and socio-economic information for policymaking can generate effective policy action to create a virtuous circle of ecosystem restoration, economic development and poverty reduction. In China, for example, economic development policy planning found that poverty-stricken areas overlapped considerably with ecologically fragile areas, requiring both poverty alleviation and ecological protection. This led to the adoption of an ecological approach to poverty alleviation, consisting of combining poverty alleviation and ecological protection programmes in the same region. China implemented more than ten programmes between 2012 and 2020, ranging from forest restoration and protection to the creation of green jobs, support for the forest industry, and ecotourism (Table 3); in total, these programmes mobilized more than USD 8.86 billion annually and helped more than 14 million people per year increase their incomes. Ecological poverty alleviation policies have been issued since 2010, mainly standardizing specific policies and measures. Overall, central and local governments have developed and implemented approaches and mechanisms such as ecological engineering construction, ecological compensation, ecological public welfare jobs, ecological characteristic industries, ecological migration, and forest-sector-targeted poverty alleviation. ■

BOX 4 A SOCIO-ECONOMIC SURVEY IN LIBERIA FINDS CONSIDERABLE FOREST-RELATED BENEFITS FOR PEOPLE LIVING NEAR FORESTS

Nearly half (47.5 percent) of Liberian households live in proximity to, and are significantly dependent on, the country's forests. The Liberian Government conducted a national household forest survey involving 3 000 forest-proximate households in 250 "enumeration areas" (administrative divisions for census and other statistical operations). The main findings include the following (all applying to 2018):

- Households collected, on average, more than 40 forest products. Seventy percent of households collected forest products for self-consumption or for both self-consumption and sale. Fuelwood, poles, rattan, wild meat and fronds were the essential products collected for cash and income generation. Income from forest products contributed, on average, 35 percent of total household incomes.
- Ninety-five percent of surveyed households relied on woodfuel for energy. Nearly all (98 percent of) households reported collecting woodfuel for their own use.
- Thirty-six percent of households used forest products for dwelling construction or maintenance. The top three forest products used in construction were poles, fronds and timber, which were rated as "very easy" to obtain from communal lands.
- Of households that sought medical assistance during the previous 12 months, more than 50 percent used medicinal plants; 77 percent of these households collected medicinal plants from communal lands.
- Survey respondents reported that forests were an important contributor to resilience, with 43 percent of households using forest products to recover from economic and natural shocks.
- Forty-six percent of households were food-insecure in the reference period of the survey, during which two-thirds of these households relied on forest products to meet their needs, with the average period of food insecurity lasting about three months.

SOURCE: World Bank. 2020. *People and forests interface – Contribution of Liberia's forests to household incomes, subsistence, and resilience.* Available at: https://openknowledge.worldbank.org/handle/10986/34438

BOX 5 THE IMPORTANCE OF TREES OUTSIDE FORESTS IN BANGLADESH

According to a national household survey conducted by the Government of Bangladesh, about 64 percent of the country's population (106 million people) – including 65 percent of the country's female population – is involved in the collection of forest products. Trees outside forests supply 98 percent of the products commonly collected by households, such as timber, bamboo, woodfuel, leaves and fruits. The estimated total national value of tree and forest primary products collected in a 12-month period in 2017–2018 was estimated at USD 8.54 billion. Households sold 31 percent of the products they collected to generate (on average) USD 81 per household per year.

SOURCE: Government of Bangladesh. 2019. *Tree and forest resources of Bangladesh – Report on the Bangladesh Forest Inventory.* Dhaka, Government of the People's Republic of Bangladesh.

TABLE 3 PROGRAMMES COMBINING POVERTY ALLEVIATION AND ECOLOGICAL RESTORATION IN CHINA, 2012–2019

Programme	Period	Investment (USD million)[b]	Forest area covered (1 000 ha)	No. of households benefited (per year)	Total no. of people participating/ benefited (per year)	No. of job opportunities created (per year)
Conversion of Farmland into Forest and Grassland (also known as "Grain for Green")	2012–2019	10 965	5 214	774 765	2 888 160	–
Natural Forest Protection	2012–2019	1 992	1 382	399 715	1 474 955	7 398 403
Beijing–Tianjin Sandification Control	2012–2019	394	535	2 307	4 332	7 630
Comprehensive Control of Rocky Desertification	2012–2019	1 328	1 932	9 837	37 125	–
Ecological compensation	2012–2019	9 228	49 316	269 635[d]	943 788	943 788
Ecological public welfare job opportunities	2016–2020	2 953	35 712	542 857[d]	1 900 000	618 717
Economic forest industry[a]	2012–2019	7 234	9 814	1 129 876	4 037 933	–
Woody oil industry[a]	2012–2019	5 606	11 604	485 000[d]	1 730 000	–
Under-forest economy[a]	2012–2019	16 783	12 565	362 632	1 199 783	–
Forest ecotourism[a]	2012–2019	14 456	15 622[c]	49 985	159 437	697 492

NOTE: [a]Data on industrial development programmes for poverty reduction cover only 22 middle and western provinces and the data on their investment are available only to 2018; [b] the exchange rate for converting Chinese yuan to United States dollars was 6.908 in 2019 (according to FAOSTAT); [c] the area of forest parks in 2018 – there were also 626 forest ecotourism centres in 2019; [d]the number of households is estimated from the total benefited population at 3.5 persons each household.
SOURCES: Data on investment in industrial development programmes and the job opportunities created by forest ecotourism are from the China Forestry and Grassland Statistical Yearbook for 2012–2018. The remaining data are from the Report on Ecological Poverty Reduction in Forestry and Grassland Sector published by China's National Forestry and Grassland Administration in April 2021.

GUYANA
A member of the Sustainable Wildlife Management Program on a Rupununi River expedition, focusing on fishing, bow-fishing and local hunting lifestyles.
©Brent Stirton/Getty Images for FAO, CIFOR, CIRAD and WCS

CHAPTER 3
THREE INTERRELATED FOREST PATHWAYS COULD CONTRIBUTE TO GREEN RECOVERY AND A TRANSITION TO SUSTAINABLE ECONOMIES

Forests have the potential to provide solutions to several growing socio-economic and environmental challenges of planetary proportions. This chapter puts forward three forest- and tree-based pathways on the understanding that any solutions have economic, social and environmental implications that need to be addressed holistically. The three pathways are (1) halting deforestation and maintaining forests; (2) restoring degraded lands and expanding agroforestry; and (3) sustainably using forests and building green value chains. Each requires integrating and balancing environmental concerns with societal and economic needs, including for recovery and sustainable development; integrating solutions to take advantage of synergies; and reducing inefficiencies to build a better and more inclusive, resilient and sustainable future.

3.1 HALTING DEFORESTATION AND MAINTAINING FOREST ECOSYSTEM SERVICES WOULD BENEFIT CLIMATE, BIODIVERSITY, HEALTH AND LONG-TERM FOOD SECURITY

HEADLINES

➔ **Halting deforestation is potentially one of the most cost-effective actions for mitigating climate change if efforts ramp up.** According to a recent estimate, halting deforestation could cost-effectively avoid emitting 3.6 +/- 2 $GtCO_2e$ per year between 2020 and 2050, including 14 percent of what is needed in 2030 to keep planetary warming below 1.5 °C. Taking advantage of REDD+ frameworks could facilitate the implementation and financing of these actions.

➔ **More efficient, productive and sustainable agrifood systems are key for meeting future needs for food while reducing demand for agricultural land, maintaining forests and securing the multiple benefits that forests**

provide to farming systems. The global population is projected to reach 9.7 billion people by 2050; taking dietary changes and other factors into account, this implies an increase in food demand of 35–56 percent, potentially increasing demand for land and pressure on forests.

➔ **The cost of global strategies to prevent pandemics based on reducing the illegal wildlife trade, avoiding land-use change and increasing surveillance is estimated at USD 22 billion to USD 31 billion.** This is a small fraction of the cost caused by a pandemic.

➔ **Multistakeholder engagement is crucial for progress in halting deforestation.** Joint public and private initiatives can deliver efficient solutions, and combinations of landscape approaches with supply-chain governance holds promise as a response to sustainable land-use challenges.

Nearly one-third of the planet's land area has been transformed in the last 60 years, and nearly 90 percent of deforestation between 2000 and 2018 was related to agriculture

Understanding of the drivers of global land-use change continues to improve as better socio-economic and environmental data and tools, including high-resolution datasets, become available. There is considerable variation in the relative importance of drivers of deforestation over time and across geographies,[97,98,99,100] with agriculture considered the most significant direct cause. FAO's recent remote sensing survey found that, between 2000 and 2018, almost 90 percent of deforestation was related to agriculture (52.3 percent from expansion for cropland and 37.5 percent from expansion for livestock grazing).[101] Cropland drove more than 75 percent of deforestation in Africa and Asia. The most significant driver in South America and Oceania was livestock grazing and, in Europe, it was infrastructure and urban expansion.[102] Other recent reports have investigated the role of underlying factors: for example, Dummet and Blundell (2021) estimated that about 40 percent of all tropical deforestation between 2000 and 2012 was driven by the illegal conversion of forestlands for commercial agriculture,[103] and Pacheco *et al.* (2021) highlighted the underlying role of landgrabbing on some deforestation fronts.[104]

It is also important to consider the dynamics of future drivers. For example, the global population is projected to reach 9.7 billion people by 2050;[105] taking dietary changes and other factors into account, this implies an increase in food demand of 35–56 percent,[106] potentially increasing demand for land and pressure on forests.

Certain trade practices involving agricuiltural and forest products could drive deforestation.[107] Although forest area has expanded in several regions worldwide, the deforestation embodied in some of their imports has increased.[108] FAO's remote sensing survey found that as much as 7 percent of global deforestation between 2000 and 2018 was due to oil-palm plantations alone,[109] of which some three-quarters of production enters international trade.[110]

Forests have a crucial role to play in enabling the world to meet the SDGs, including those related to biodiversity conservation, livelihoods, food security, mitigating natural risks, and climate-change mitigation and adaptation. Continued deforestation would have significant consequences that nevertheless are difficult to estimate due to a range of uncertainties and the potential for tipping points, thresholds and feedbacks. For example, models show that the Amazon biome could cross a tipping point if deforestation exceeds 40 percent of the original forest area, triggering a transition to savannah ecosystems, with consequences and costs that cannot readily be assessed.[111]

Halting deforestation could be one of the most cost-effective actions for mitigating and adapting to climate change and reducing biodiversity loss

Climate change. The Sixth Assessment Report of the Intergovernmental Panel on Climate Change made it clear that climate change is widespread, rapid and intensifying and that only rapid and drastic reductions in GHGs in this decade can prevent climate breakdown.[112] All pathways developed by the Intergovernmental Panel on Climate Change consistent with

limiting the mean temperature rise to less than 1.5 °C compared with the preindustrial period require human activity to become carbon-neutral by 2050. Analysis shows that, in addition to rapid decarbonization across economies, significant mitigation will be required from land-based options.[113] Halting deforestation, which will involve actions to protect, sustainably manage and restore natural and modified ecosystems, provides significant climate and other benefits, including adaptation and resilience. Halting deforestation would avoid direct emissions from the lost biomass as well as maintain the capacity of forests to absorb carbon and support resilience and sustainable livelihoods.

Forests are both a source and a sink of GHG emissions. Net anthropogenic emissions from forests and land use (mostly, in practice, the conversion of forests and peatlands) between 2007 and 2016 were 5.8 +/- 2.6 $GtCO_2e$, which was about 11 percent of global CO_2e emissions.[114] On the other hand, forests have delayed climate change by absorbing a significant portion of CO_2 emissions from human activities[115] – some 11.2 +/- 2.6 $GtCO_2$ per year between 2007 and 2016.[116] This buffering capacity is threatened by deforestation and forest degradation (including that caused by climate change). In the absence (at present) of other proven technologies for capturing carbon at scale, forest maintenance and restoration are the only ways to remove significant volumes of CO_2 from the atmosphere.

In some cases, deforestation is irreversible (and, in others, recovery might be very slow), which is an additional source of concern and reinforces the need to halt deforestation as a means for addressing climate change. Globally, ecosystems at risk of deforestation or degradation contain at least 260 Gt of irrecoverable or difficult-to-recover carbon, particularly in peatlands, mangroves, old-growth forests and marshes.[117] Unless additional actions are taken, an estimated 289 million ha of forests would be deforested between 2016 and 2050 in the tropics alone, resulting in the emission of 169 $GtCO_2e$.[118] Thus, halting deforestation and preventing forest degradation is one of the most important actions for reducing GHG emissions and removing CO_2 from the atmosphere.

A recent assessment of multiple studies identified a technical potential for reduced deforestation of 3.1–8.9 $GtCO_2$ per year and a cost-effective climate-change mitigation potential of 1.6–5.6 $GtCO_2$ (average 3.6 $GtCO_2$) per year (Table 4).[119] Technical potential refers to what is possible with current technology, regardless of cost, and cost-effective potential is the estimated potential with a cost of up to USD 100 per tCO_2e, which is considered within the range of what is needed to meet Paris Agreement goals; cost-effective potential is more relevant for policymaking and national planning. Thus, halting deforestation could have significant cost-effective potential relative to mitigation options in other sectors.[120] Of the forest options (reducing tropical deforestation, improving forest management globally, and afforestation/reforestation globally), reducing tropical deforestation could account for two-thirds of the cost-effective potential.[121] It has also been suggested that investing in the comparatively lower cost of forest-based mitigation would result in an overall lower cost for meeting climate targets globally and potentially release funds that could be used for further mitigation actions.[122]

Biodiversity. As detailed by FAO (2019), biodiversity is indispensable for food security, sustainable development and the supply of ecosystem services.[123] An estimated 75 percent of the 115 leading food crops globally – together representing 35 percent of global food production – benefit from pollination by animals,[124] many of which live in forests. Biodiversity continues to decline worldwide, however, and current actions are inadequate for ensuring its conservation and sustainable use and for achieving sustainable development.[125] To reverse the trend of biodiversity loss, a transformative change is needed to tackle its root causes – that is, the interconnected economic, sociocultural, demographic, political, institutional and technological indirect drivers behind the direct drivers.[126] Deforestation poses a serious threat to biodiversity because it leads to a disproportionate loss of species' distributions, increasing the risk of extinctions.[127]

Enhancing measures to conserve and sustainably use biodiversity requires significant investment. In addition to managing forests more sustainably, protecting them is part of a mix of solutions. »

TABLE 4 ANNUAL TECHNICAL AND COST-EFFECTIVE MITIGATION POTENTIAL OF THE MAIN FOREST CLIMATE-CHANGE MITIGATION OPTIONS GLOBALLY, 2020–2050

Technical potential		Africa	Asia	Europe	North and Central America	Oceania	South America	Total
					($GtCO_2e$/year)			
Avoided deforestation	Minimum	0.8	0.6	-	0.1	0.0	1.5	3.1
	Average	1.6	1.4	-	0.2	0.2	2.6	6.0
	Maximum	2.4	2.2	-	0.4	0.3	3.7	8.9
Afforestation/ reforestation	Minimum	0.2	1.2	2.2	0.1	0.1	1.8	5.5
	Average	1.6	1.8	2.2	0.3	0.1	2.4	8.5
	Maximum	3.1	2.4	2.2	0.6	0.2	3.0	11.4
Improved forest management	Minimum	0.1	0.3	0.3	0.0	0.0	0.0	0.8
	Average	0.2	0.8	0.5	0.0	0.1	0.2	1.8
	Maximum	0.3	1.3	0.6	0.1	0.1	0.4	2.9

Cost-effective potential		Africa	Asia	Europe	North and Central America	Oceania	South America	Total
					($GtCO_2e$/year)			
Avoided deforestation	Minimum	0.5	0.3	-	0.0	0.0	0.7	1.6
	Average	1.0	0.8	-	0.1	0.1	1.5	3.6
	Maximum	1.4	1.4	-	0.2	0.2	2.4	5.6
Afforestation/ reforestation	Minimum	0.1	0.2	0.3	0.0	0.0	0.3	0.9
	Average	0.3	0.3	0.3	0.1	0.0	0.3	1.2
	Maximum	0.4	0.3	0.3	0.1	0.0	0.4	1.5
Improved forest management	Minimum	0.1	0.1	0.1	0.0	0.0	0.0	0.4
	Average	0.2	0.4	0.2	0.0	0.0	0.1	0.9
	Maximum	0.3	0.6	0.2	0.0	0.1	0.2	1.5

NOTE: Technical mitigation potential is defined as the maximum mitigation potential that can be delivered by current technologies while meeting human needs for food and fibre. Cost-effective mitigation potential refers to the potential constrained by carbon price, based on an assumed social price of carbon. Cost-effective potential represents the public willingness to pay and provides an indication of near-term feasibility for reducing emissions and enhancing sequestration and is therefore more relevant for policymaking and national plans. While other factors (e.g. political, structural and social) affect feasibility, to our knowledge no data on mitigation potential consider these factors. The estimates here are derived from Roe *et al.* (2021), who considered recent global mitigation potential estimates at the country level. They are indicative and based on studies that may combine estimates from several sources and reflect different methodologies that may not lend direct comparison or addition. Figures should therefore be viewed with caution but provide an indication of the sector's scale of contribution.

SOURCES: FAO calculations based on Roe *et al.* (2021) and also drawing on Austin *et al.* (2020) and Busch *et al.* (2019).

Roe, S., Streck, C., Beach, R., Busch, J., Chapman, M., Daioglou, V., Deppermann, A. et al. 2021. Land-based measures to mitigate climate change: potential and feasibility by country. *Global Change Biology*, 27(23): 6025–6058. https://doi.org/10.1111/gcb.15873

Austin, K.G., Baker, J.S., Sohngen, B.L., Wade, C.M., Daigneault, A., Ohrel, S.B., Ragnauth, S. et al. 2020. The economic costs of planting, preserving, and managing the world's forests to mitigate climate change. *Nature Communications*, 11(1): 5946. https://doi.org/10.1038/s41467-020-19578-z

Busch, J., Engelmann, J., Cook-Patton, S.C., Griscom, B.W., Kroeger, T., Possingham, H. & Shyamsundar, P. 2019. Potential for low-cost carbon dioxide removal through tropical reforestation. *Nature Climate Change*, 9(6): 463–466. https://doi.org/10.1038/s41558-019-0485-x

» For example, an analysis by Waldron *et al.* (2020) suggested that the cost of protecting forests and mangroves on 30 percent of the Earth's surface would require an annual investment of USD 140 billion;[128] although considerable, this would be only about one-quarter of the global government subsidies currently channelled to activities that are harmful for forests (and therefore biodiversity) (see Chapter 4). However, no conclusions have been made in intergovernmental debates on whether any increase in forest protected areas at the global level would be feasible or desirable due to the complex trade-offs involved.

Hydrologic services. Sustainably managed forest ecosystems help regulate hydrologic cycles and can reduce the likelihood of agricultural losses from drought, soil erosion, landslides and floods.[129] The ability of forests to provide services related to water quality, quantity and timing is closely linked to changes in land use and management as well as to the spatial and temporal scales at which forest–water interactions happen. In an analysis of 230 of the world's major watersheds, those that had lost more than 50 percent of their original tree cover (as of 2015) were assessed to have a medium to high risk of erosion (88 percent risk), forest fire (68 percent) and water stress (48 percent).[130] Forests in upper watersheds regulate waterflows and contribute to groundwater recharge as well as soil conservation. Forested watersheds provide three-quarters of accessible freshwater,[131] including resources for many irrigated areas. Forest conservation can help reduce the cost of water treatment.[132]

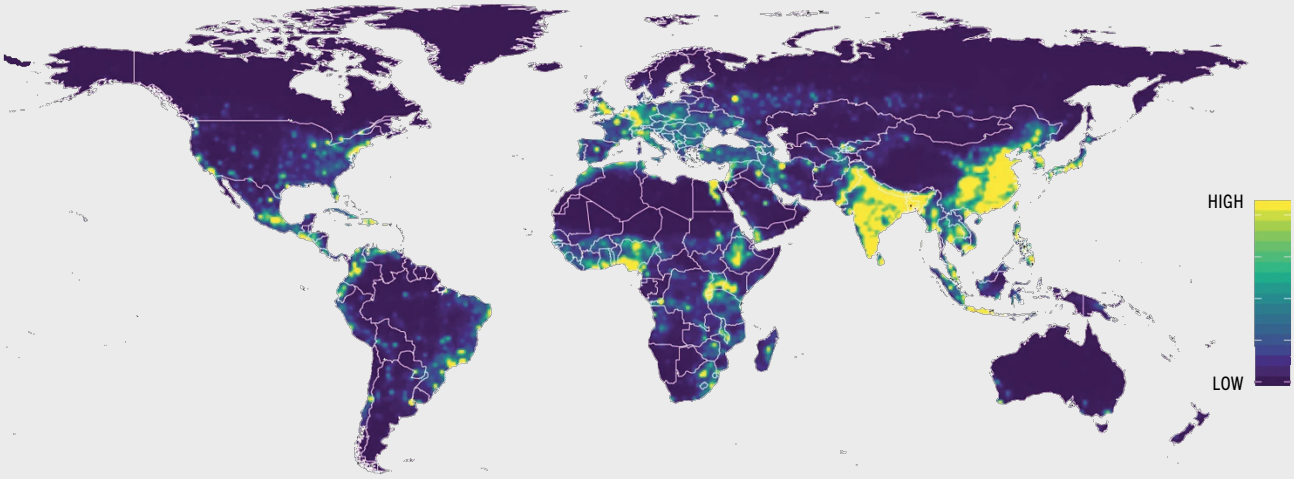
Investment in forests could be a cost-effective measure for water management.[133,134] In Mumbai, India, for example, water turbidity increased by 8.4 percent for every 1 percent of forest-cover loss, resulting in an increase of around 1.6 percent in the cost of treating drinking water.[135] In Zambia, the saving obtained from forest management to reduce sedimentation in reservoirs has been estimated at USD 123 million to USD 247 million per year (USD 1.2 to USD 2.9 per ha per year), depending on the type of dam.[136] Reducing sedimentation in reservoirs also increases the lifespan, usefulness and sustainability of the infrastructure, which could mean that fewer dams need be built.[137,138,139]

Disasters. Forests can cost-effectively mitigate disasters. For example, mangroves protect an estimated USD 65 billion in property values and about 15 million people against extreme weather events.[140] The loss of existing mangrove cover could increase the number of affected people by 28 percent, the area of land flooded by 29 percent and the value of property damaged by 9 percent; the benefits of mangroves for risk reduction tends to increase with the intensity of flooding events.[141]

Emerging infectious diseases. Analysis of the spatial patterns of the origins of EIDs suggests that both deforestation and reforestation are correlated with a heightened risk of disease emergence globally. Notably, hotspots of concern are tropical forest regions experiencing rapid land-use change and population growth and where mammalian biodiversity is high (Figure 8);[142] such hotspots could be targeted for prevention at source and for preparedness efforts. Forest ecosystem alteration is a major landscape-level contributor to disease emergence.[143] In general, disease risk increases when transitions between forest contexts occur, such as the conversion of forest to agriculture, road opening, mining, and other industrial activities. A study in Senegal found that high levels of antibodies against the mosquito-borne virus *Chikungunya* in humans were significantly associated with residence near forest areas and gold-mining activities (which often involve increased human presence at mining sites, along with ecological changes).[144]

There is growing evidence that pathogen spillover, amplification and spread is driven largely by consumption patterns set up by globalized production and trade, which drive encroachment into tropical ecosystems, particularly forested regions (e.g. for crop and livestock production, timber, mining, and the manufacture of goods).[145] The cost of global strategies to prevent pandemics based on reducing land-use change and the illegal wildlife trade and increasing surveillance is estimated at USD 22 billion to USD 31 billion, but it could be lower (USD 17.7 billion to USD 26.9 billion) if the benefits of reduced deforestation for carbon sequestration are considered.[146] These cost estimates are two orders of magnitude less than the cost caused by a pandemic, providing a strong economic incentive for transformative change »

FIGURE 8 "HOTSPOTS" MAP SHOWING THE PREDICTED DISTRIBUTION OF ZOONOTIC DISEASE EMERGENCE RISK FROM WILDLIFE



NOTE: Yellow indicates areas of highest relative risk and purple indicates lowest risk. Adjusted for reporting bias.
SOURCE: Allen, T., Murray, K.A., Zambrana-Torrelio, C., Morse, S.S., Rondinini, C., Di Marco, M., Breit, N. *et al.* 2017. Global hotspots and correlates of emerging zoonotic diseases. *Nature Communications*, 8(1): 1124. https://doi.org/10.1038/s41467-017-00923-8

BOX 6 ONE HEALTH

The human-health benefits of forests, and people's needs, vary by context, particularly between rural and urban areas. One Health is an integrated approach recognizing that the health of people is closely connected to the health of animals and our shared environment; it aims to ensure that experts, policymakers and stakeholders in multiple sectors work together to tackle health threats to animals, humans, plants and the environment. The One Health approach has the potential to reduce disease transmission risks and improve the health and well-being of all people, wildlife, livestock and ecosystems. To date, most One Health efforts have invested primarily in public health sectors, followed by the veterinary sector; it has become apparent, however, that addressing the ecosystem-health dimension through responsible land-use planning and the greater involvement of the forest and wildlife sectors and natural-resource managers is equally important.[148] Continuous monitoring and surveillance, data-sharing and evidence-based decision-making are essential for minimizing impacts and adjusting policies over time and as conditions change.

» to reduce the risk of pandemics.[147] Among other things, the forest ecosystem dimension of the One Health approach needs strengthening to address underlying drivers of disease emergence (Box 6).

Multiple benefits are to be gained from halting deforestation and maintaining forests, locally and globally as well as in the short and long terms, including the potential to contribute to a green recovery from the COVID-19 pandemic. A significant part of this goal can be achieved cost-effectively. The joint prioritization of the objectives of sequestering carbon and protecting biodiversity, water and other values would likely identify significant overlaps between these objectives and thus opportunities to increase cost-efficiency. For example, one joint prioritization exercise estimated that the top 30 percent of priority areas globally would conserve about two-thirds of existing carbon stock, clean water and species.[149]

Policy responses for halting deforestation typically involve creating incentives for forest conservation, addressing the potential conflicts with development pathways, food security and economic needs, and investing in enabling conditions for more efficient land-use decisions. Here, we highlight some of the policy responses available to advance the halting-deforestation pathway.

REDD+. REDD+ is a framework created under the United Nations Framework Convention on Climate Change (UNFCCC) to guide and reward results from policies and actions that reduce emissions from deforestation and forest degradation and encourage the sustainable management of forests and the conservation and enhancement of forest carbon stocks in developing countries; it could be a key mechanism for halting deforestation and meeting climate goals and for countries to receive results-based payments (RBPs). Building on the REDD+ framework, countries can meet and enhance their nationally determined contributions (NDCs) to climate-change mitigation under the Paris Agreement, with many countries recognizing the mitigation potential of forests in their recent NDCs. REDD+ actions can also be linked to carbon-financing opportunities provided by Article 6 of the Paris Agreement (see Chapter 4) and complement country efforts to implement their national adaptation plans.

The participative processes and capacity development inherent in REDD+ preparation and implementation have created the conditions for action, but implementation is still needed at scale. At the national level, greater articulation between REDD+ strategies and agricultural policies could be crucial for addressing deforestation drivers, many of which relate to commodity production. Where REDD+ RBPs for emission reductions have been obtained, they can be invested in more forest-positive agrifood systems, feeding a virtuous circle between sustainable rural development and climate achievements.

Enabling and implementing integrated sustainable land management. Integrated landscape governance approaches are inherently cross-sectoral. They seek to coalesce partners, provide directionality and facilitate action within a specific jurisdiction or landscape at the subnational level.[150] Such approaches are complex and can take many forms based on the local context. Five key components are emerging as minimum requirements to enable the localized reduction of deforestation from agricultural expansion: (1) multistakeholder partnerships built around a common agenda; (2) consistent neutral technical support and capacity development; (3) integrated land-use planning; (4) shared monitoring and information systems; and (5) funding the transformation to forest-positive landscapes.[151,152]

In addition, collaboration among public bodies and the active engagement of stakeholders, including women and marginalized communities, are needed so that the plans are informed by the interests and needs of these different groups; clear, secure land tenure is another necessary foundation for long-term sustainable investment and coordination (see Chapter 5). Governments can play a significant role by providing the legal and technical conditions necessary for enabling Indigenous Peoples, local communities, smallholders, women, youth and other vulnerable groups and their local social organizations to manage larger territories.

Strengthening governance. Legal economic activity, including forest and agricultural

BOX 7 THE GLOBAL ENVIRONMENT FACILITY'S FOOD SYSTEMS, LAND USE AND RESTORATION PROGRAM

The aim of the Global Environment Facility's Impact Program on Food Systems Land Use and Restoration, launched in November 2021, is to reduce the negative impacts of food production systems in 27 country-level projects and across eight production and value chains covering beef, cocoa, corn, coffee, palm oil, rice, soy and wheat. The anticipated results will be achieved by establishing sustainable land-use and agrifood-supply systems that avoid or reduce deforestation at scale. All projects follow a programmatic approach comprising three key components: (1) the development of integrated landscape management systems; (2) the promotion of sustainable food production practices and responsible commodity value chains; and (3) the restoration of natural habitats.

SOURCE: World Bank. 2021. Home page | Folur. In: *FOLUR - food, land use, restoration* [online]. [Cited 31 March 2022]. https://folur.org/

production, is vital for realizing sustainable land management, and strengthening land-use planning and governance and supporting law enforcement and accountability processes can be key for reducing negative trade-offs between agriculture and forests. This includes fostering innovative approaches for traceability, accountability and capacity development in the context of agricultural and wood (and NWFP) value chains.

Adaptation to climate change. There is increasing evidence that the loss and degradation of ecosystems, including forests, increases the vulnerability of people to climate change, especially Indigenous Peoples and local communities.[153] Forest ecosystem services enhance the adaptive capacity and resilience of people and ecosystems through (for example) water and temperature regulation, flood-risk reduction, nutrient cycling, pollination, resource provision and cultural services. Ecosystem-based adaptation approaches can reduce climate-change risks for people, biodiversity and ecosystem services, but their effectiveness declines with increased global warming, underscoring the importance of pursuing mitigation–adaptation synergies in climate action. The role of forests and trees in enabling people to adapt to climate change and enhancing the resilience of farming systems, other economic sectors and human infrastructure is increasingly recognized and included in national adaptation plans.[154]

Increasing agricultural productivity on existing land, especially for smallholder farming, is essential for halting deforestation

Competition for land between agriculture (croplands and pasturelands) and forests and other natural ecosystems has a close relationship with the technical features of agrifood systems, including yields and markets. Agricultural production more than tripled between 1960 and 2015,[155] whereas the area of agricultural land increased by only about 27 percent over the same period.[156] Globally, only 30 percent of the arable land area was needed in 2014 to produce the same quantity of crops produced in 1961,[157] showing the significant impact of productivity gains in limiting demand for additional land.

Productivity-enhancing technologies have helped partially decouple increases in agricultural production from agricultural expansion but can also have unintended environmental impacts (e.g. soil degradation, biodiversity loss, water pollution, pest outbreaks and GHG emissions) due to excessive reliance on monocropping, fertilizers and pesticides.[158] Nevertheless, Byerlee *et al.* (2014) found that intensification can help minimize cropland expansion and slow deforestation at the local level, especially if it occurs away from the forest frontier, is knowledge- and technology-driven rather than market-driven, and is locally

adapted, as appropriate.[e,159] An increase in yields may also act as an incentive for future deforestation by increasing the potential revenue from deforested land in the absence of additional measures aimed at limiting forest change.

Yield increases have differed between crop and livestock systems and among countries. Less progress in increasing agricultural productivity in many sub-Saharan African countries (due in part to a lack of capacity among smallholders arising from, for example, a lack of access to resources and technologies) has led to larger areas of land used for cereal production,[160] among other key crops. In such countries, increasing yields of widely cultivated crops and staple foods[161,162] could be a way to reduce pressure on forests. Mosnier *et al.* (2015) tested the impact on deforestation of increasing yields in the main crops in Cameroon and the Democratic Republic of the Congo and found a reduction in deforestation (compared with the baseline) of 33 percent in the former and 27 percent in the latter.[163,164]

Some global scenarios derived from partial equilibrium models project reductions of cropland expansion in 2030 and 2050 due to yield increases, including: a net-zero expansion at the global level in 2030 where per-hectare crop yields increase twice as fast as the historical average in emerging and developing countries (2 percent per year and 2.3 percent per year, respectively);[165] and a reduction of 21 percent in the expansion of cropland in 2050 where yields increase by 20 percent above the baseline scenario with improved adaptation to climate change.[166] Several studies have shown that increases in the productivity of croplands and cattle ranching, combined with appropriate market and public policies, could help stabilize the forest frontier in the Brazilian Amazon.[167,168] Garcia *et al.* (2017) assessed the economic and environmental feasibility of sustainable livestock intensification[f] on a deforestation frontier in the Brazilian Amazon; they found that conversion was economically viable on medium-to-large farms in that municipality.[169] The cost of reaching the yields that could limit encroachment on forests is difficult to assess at the global level; Krause *et al.* (2013) modelled the economic impacts of prioritized forest conservation on agriculture and found that production costs would increase by a maximum of 4 percent, driven predominantly by increased investment in agricultural productivity.[170]

The scientific evidence for agricultural intensification[g] as a means for limiting future deforestation is still limited, however.[171] Positive synergies or negative trade-offs might be observed, depending on the nature of the intensification, including the target market for produced commodities, the distance of the place of implementation from deforestation fronts,[172] and the effectiveness of land governance.

Thus, although improved technology in agricultural production cannot be a stand-alone solution, investment in research and development and technical assistance is needed to increase agricultural productivity as an essential cost-effective contribution to reducing deforestation.[173] To be transformative, technical progress must be embedded in integrated approaches, including strong land and forest governance, an appropriate legal framework and related law enforcement, and complementary measures such as strongly supported protected-area systems and value chains that distribute benefits fairly and ensure that producers earn a sufficient living income.[174]

Companies are increasingly committing to zero deforestation in value chains, but more action is needed

A growing number of companies are signing up to deforestation commitments, but progress in achieving results is slower than needed. An increasing number of datasets and studies have highlighted the link between agricultural

e Technology-driven intensification occurs when technical change in a crop allows more output per unit of land for the same level of inputs. Market-driven intensification results from a shift in product mix to higher-value crops due to new market opportunities, or from a shift in the input mix in response to relative price changes.

f The intensification model adopted was based on a conservative carrying capacity of 3 animal units per ha to avoid negative environmental impacts associated with overgrazing, manure and the use of fertilizers, and CO_2 and methane emissions.

g Agricultural intensification is understood here as an increase in the productivity of land measured by the real value of agricultural output per ha.

land expansion and deforestation, and public and private awareness and commitment to address this negative trade-off have grown concomitantly. In recent years, countries, subnational governments, civil society and the private sector have broadly adopted the objective of reducing, halting and reversing forest loss, including through initiatives such as the New York Declaration on Forests, the Consumer Goods Forum, the Amsterdam Declarations, the UN Secretary General's initiative on turning the tide on deforestation and, more recently, the Glasgow Leaders' Declaration on Forests and Land Use. Most of these instruments define specific goals for decoupling agricultural production from deforestation.

Many companies have adopted measures aimed at ensuring sustainability in their supply chains,[175] such as codes of conduct, due diligence, certification schemes, the exclusion of specific providers or areas of supply, spatial monitoring systems and traceability instruments.[176,177] Some initiatives have been undertaken for specific commodities, like the Amazon Soy Moratorium signed in 2006, in which 90 percent of companies in the Brazilian soy market committed to avoiding the purchase of soy grown on recently deforested areas in the Brazilian Amazon. Around 500 major food retailers, traders and processors now have guidelines or commitments on reducing the risk of deforestation or forest degradation in their value chains.[178] The market share of companies with some form of deforestation-free commitments varies across products, ranging from about 12 percent for soy, livestock and pulp and paper to 65 percent for palm oil.[179]

Hundreds of companies have identified business risks associated with deforestation and consequently adopted measures to reduce these. Among them, 151 companies assessed the financial impact of such risks at USD 53.1 billion and the cost of responding to those risks at just over USD 6.6 billion. Some 131 companies considered that ensuring that their value chains are not associated with deforestation represents a business opportunity that could be valued to USD 35.6 billion.[180]

Initiatives to assess deforestation risk are also emerging. For example, in 2019 the CDP[181] requested on behalf of its investors that more than 1 400 companies report on five forest-risk commodities – timber, palm oil, cattle, rubber and soy – and 21 percent (300 companies) complied. Through its supply-chain initiative, the CDP also requested disclosure on climate impacts from companies in the supply chains of high-forest-risk companies on behalf of the purchasing companies, and about 60 percent (399 suppliers) complied.

Despite such efforts, progress among companies with forest-risk supply chains appears slow. A recent assessment of the world's 350 most influential companies linked to deforestation in supply chains found that 252 (72 percent) did not have a deforestation commitment for all forest-risk commodities in their supply chains, 117 had no deforestation commitments at all, and, for many companies with commitments, evidence of implementation was lacking.[182]

The UN Food Systems Summit, held in September 2021, addressed the decoupling of agricultural commodities from deforestation. A range of announcements on deforestation were made at the 26th Conference of the Parties (COP) to the UNFCCC, including significant pledges of financial contributions (Box 8; see also Chapter 4).

To contribute to private sector momentum towards greater social responsibility, an increasing number of governments around the world are incorporating the Organisation for Economic Co-operation and Development–FAO Guidance for Responsible Agricultural Supply Chains – a global standard for addressing risk and development in the agriculture sector – into their corporate sustainability policies, linking investment, enterprise, agriculture and development.

Governments can play major roles in halting deforestation, including in public–private approaches

Public-sector involvement is important for increasing the positive impacts of business initiatives to limit deforestation and forest degradation in supply chains. Governments of producer countries can set enabling legal frameworks; steer land-use planning; establish

BOX 8 THE 2021 UN FOOD SYSTEMS SUMMIT, AND THE FOREST, AGRICULTURE AND COMMODITY TRADE DIALOGUES

Decoupling agricultural commodities from deforestation has been addressed at the UN Food Systems Summit in September 2021 under Action Track 3 "Boost nature-positive production",[183] to be followed up by a coalition called Halting Deforestation & Conversion from Agricultural Commodities.

In the context of the 26th Conference of the Parties (COP 26) to the UN Framework Convention on Climate Change, 11 country and philanthropic donors pledged USD 1.5 billion to protect forests in the Congo Basin. Twenty-eight governments signed the Forest, Agriculture and Commodity Trade Statement to deliver sustainable trade and reduce pressure on forests, including by providing support for smallholder farmers and improving the transparency of supply chains. Ten of the largest private sector companies managing over half the global trade of key forest-risk commodities such as palm oil and soy announced that they would develop a roadmap for enhanced supply-chain action by COP 27.

protected areas;[184,185] ensure the coherency of fiscal incentives and forest and agricultural policies; improve law enforcement and monitoring; clarify the collective rights of Indigenous Peoples and local communities, which have been associated with improved forest stewardship (see also Chapter 5);[186,187,188] support capacity development, especially for small farmers and small and medium-sized enterprises; provide guidance on traceability and chain-of-custody tools; introduce specific requirements in public procurement for goods and services; develop reliable and accessible information systems; and put adequate mechanisms in place to avoid the risk that small and medium-sized enterprises will lose access to markets because of stringent requirements related to the risk of deforestation. Robust monitoring and information for decision-making are enabling factors for improving governance and informing land-use decisions – such as the use of near-real-time deforestation alerts.[189]

Initiatives involving integrated public–private approaches to addressing deforestation and forest degradation are increasing – for example, the zero-deforestation commitments made for five commodities in Colombia and the Cocoa & Forests Initiative in Côte d'Ivoire and Ghana (Box 9). In Brazil, the reduction in the rate of deforestation of more than 80 percent achieved between 2004 and 2014 has been attributed to a combination of government policies (e.g. stronger law enforcement), supply-chain interventions (including private commitments on soy and cattle), and changes in market conditions.[190,191] Governments can also take legal action to prevent deforestation caused by specific commodities. For example, Indonesia adopted a temporary moratorium (in force from September 2019 to September 2021) on the expansion of oil-palm plantations and imposed (in 2019) a permanent ban on the clearing of primary forests and peatland – affecting both oil-palm and timber plantations – on 66.2 million ha of these strategic ecosystems.

The opportunity cost of halting deforestation on agricultural revenue is significant – one estimate puts it at nearly USD 800 per ha per year in the Brazilian Amazon

The opportunity cost of conserving forests on the agricultural revenue obtained from deforested lands is a key factor for assessing the potential of instruments designed to add value to forests. For example, using census and deforestation data for municipalities in the Brazilian Legal Amazon Region, de Figueiredo Silva *et al.* (2018) estimated the shadow price of reducing deforestation in terms of agricultural income foregone at minus USD 797 in annual agricultural GDP per ha of forest conserved.[193] Increasing the economic value

BOX 9 PUBLIC–PRIVATE COLLABORATION ON ZERO-DEFORESTATION VALUE CHAINS

Zero-deforestation agreements in Colombia. The Colombian Government included in its 2018–2022 national development plan the objective of setting up zero-deforestation agreements for five agricultural value chains – palm oil, cattle meat, dairy products, coffee and cocoa. The aim is to ensure zero gross deforestation by 2025 in these value chains. An already significant and growing share of the national market for the five commodities is covered by the agreements – including, for example, 15 coffee production companies commanding 90 percent of the national market and six companies representing 85 percent of the market for cocoa. Multistakeholder platforms are at the heart of the initiative, with all categories of player along the value chains – government and other public entities, companies of different sizes and roles, farmer organizations, commodity-based professional unions, research centres, non-governmental organizations and international initiatives – involved in the collective effort.

SOURCE: R. Rodriguez, Ministerio de Ambiente y Desarrollo Sostenible, Colombia, personal communication, 22 September 2021.

The Cocoa & Forests Initiative. Cocoa production is one of the most important sources of income in West Africa, involving around 2 million small producers whose livelihoods depend directly on this crop. Cameroon, Côte d'Ivoire and Ghana produce around 68 percent of cocoa worldwide, but the crop also caused the deforestation of around 2.3 million ha between 1998 and 2007. In these countries, public–private partnerships are being established to scale-up zero-deforestation production and increase traceability and responsible sourcing by taking advantage of REDD+ frameworks.[192] Since 2017, the governments of Côte d'Ivoire and Ghana and 35 leading cocoa and chocolate companies have joined together to eliminate cocoa-related deforestation and restore forest areas, committing to aligning their actions in four areas of work, with shared responsibilities. Côte d'Ivoire has adopted a national satellite system to monitor deforestation for the Initiative. Cocoa and chocolate companies reached 82 percent (Ghana) and 74 percent (Côte d'Ivoire) traceability in direct sourcing in 2020. Some 620 000 farmers have been trained in good agricultural practices for "more cocoa on less land" and "climate-smart cocoa" and innovative financial models have been developed, including payments for ecosystem services to farmers in Côte d'Ivoire and collective mechanisms like village savings and loan associations.

SOURCE: Cocoa & Forests Initiative. Undated. *Annual report Cocoa & Forests Initiative 2020*. (also available at https://www.idhsustainabletrade.com/uploaded/2021/05/NUM_ANG_RAPPORT_ICF_VF1.pdf).

of forests for local actors can provide an incentive to halt deforestation, supported by sustainably increasing agricultural productivity; moreover, efforts are needed to address constraints on smallholders in accessing incentives and increasing productivity. Incentive measures to address opportunity costs might include payments for ecosystem services[194,195] and subsidy reforms.[196] Market incentives should be aligned with forest conservation and ensure support along supply chains.[197,198] An analysis by Börner *et al.* (2020) suggests that, although the protection of indigenous lands and payment schemes for ecosystem services have shown relatively high effectiveness in conserving forests, the intervention context matters.[199]

There is patchy empirical evidence on the costs and benefits of halting deforestation. A literature review by Rakatama *et al.* (2017) estimated the mean opportunity cost at USD 11.13 per tCO_2e; transaction and implementation costs at USD 3.39

per tCO_2e; and total costs at USD 24.87 per tCO_2e.[200] The estimated direct monetary benefits were significant and thus an important element in the rationale for forest protection, at USD 17.37 per tCO_2e. These estimates vary considerably with location and time and in relation to socio-economic conditions – for example, an increase in world demand for agricultural commodities would raise the opportunity cost of forest conservation.[201] Generally, however, it is likely to be cheaper to halt deforestation than to restore degraded lands later.

Additional incentives may be needed. According to a recent report on progress towards achieving the goals established in the 2014 New York Declaration on Forests, "All assessment indicators show either insufficient progress towards ending forest loss and associated GHG emissions by 2030 or that we are moving further from the targets".[202] For example, according to the report, humid tropical primary forest loss is well above levels before the New York Declaration on Forests, "with an average of 41 percent more loss each year" after the declaration was signed than before.[203] Although numerous companies are signing up to deforestation commitments, progress in achieving results needs to accelerate.

Incentive schemes for the provision of forest ecosystem services are emerging, mostly focused on carbon. The voluntary forest carbon market is potentially important, although, despite early enthusiasm, it has grown only slowly. With increasing global efforts to decarbonize economies, investment in climate finance is projected to grow to USD 60 trillion by 2050 (see Chapter 4). This is likely to create huge opportunities for forest-based carbon credits because demand and prices for offset credits are expected to rise. REDD+ mechanisms are also providing options for countries to receive results-based finance.

In some contexts, forest-based tourism can be important for generating economic and employment opportunities for women, youth and other vulnerable groups. Aligning incentives created by policies and providing other support to recognize the role of forests could contribute to halting deforestation; such measures are discussed in Chapter 4. ■

3.2 FOREST AND LANDSCAPE RESTORATION AND AGROFORESTRY HELP DIVERSIFY LIVELIHOODS AND LANDSCAPES AND INCREASE LAND PRODUCTIVITY

HEADLINES

➔ **Large areas of degraded land would benefit from restoration involving trees.** Of the 2.2 billion ha of degraded land identified as potentially available for restoration worldwide, 1.5 billion ha may be best suited for mosaic restoration combining forests and trees with agriculture.

➔ **Restoration involving trees can provide large environmental and economic benefits.** For example, restoring degraded land through afforestation and reforestation could cost-effectively take 0.9–1.5 $GtCO_2e$ per year out of the atmosphere between 2020 and 2050. The restoration of 4 million ha of degraded land in the Sahara and the Sahel area has created more than 335 000 jobs.

➔ **The scaling up of restoration and agroforestry is hindered by the time required to obtain profitable returns.** For example, agroforestry can increase crop productivity in many local contexts, but obtaining a profitable return can take up to eight years compared with 1–2 years for annual crops.

The United Nations has declared 2021–2030 the Decade on Ecosystem Restoration, with the aims of preventing, halting and reversing ecosystem degradation on every continent and in every ocean; building political momentum; and creating a global movement and scaling up successful

restoration actions. "Avoid degradation", "reduce degradation" and "restore degraded land" are the three aspects of the response hierarchy in the forest and landscape restoration (FLR) approach.[204] Restoration can pay its way, but it is usually cheaper to maintain ecosystems than to let them degrade and then undertake restoration.[205] This section examines tree-based strategies for restoring degraded land, increasing agricultural productivity and maintaining or restoring ecosystem services with a view to increasing the resilience of both ecosystems and people.

In diverse contexts, the cost of restoration is much lower – up to 26 times – than the cost of inaction, and the environmental benefits can be considerable

An assessment in 42 African countries showed that the benefit of land restoration and conservation for agricultural productivity is 3–26 times greater than the cost of inaction.[206] Mirzabaev *et al.* (2021) demonstrated that, in scenarios developed for Great Green Wall (GGW) countries, the costs of land restoration (cost of action) are lower than the costs of inaction, thus providing a strong economic justification for land restoration activities in the Sahel.[207]

Restoring degraded ecosystems can both enhance the provision of ecosystem services such as biodiversity conservation and water and climate regulation and spur economic growth – now, and beyond the pandemic.[208] A meta-analysis of 89 studies in a broad range of ecosystem types worldwide, including forests, found that restoration increased the provision of biodiversity and ecosystem services by an average of 44 percent and 25 percent, respectively, relative to levels in degraded systems (measures of biodiversity were related to the abundance, species richness, diversity, growth and biomass of organisms present).[209]

Restoration can enhance key ecosystem services like water regulation and quality. Burek *et al.* (2016) estimated that 4.8 billion–5.7 billion people could be living in water-scarce areas at least one month per year by 2050.[210]Investing in healthy forests would help in sustaining water services, with FLR a cost-effective measure for maintaining water-holding capacity, soil fertility and soil stability.[211]

The potential effects of restoration at the global level can be huge. Van der Esch *et al.* (2021) estimated that, between 2015 and 2050, without land restoration measures (baseline scenario), soil and biomass productivity will be negatively affected on 12 percent of the global land area; croplands will expand by about 20 percent (approximately 300 million ha) at the expense of natural areas; 6 percent of remaining biodiversity will be lost due to land-use change, intensive production and climate change; and average annual carbon emissions from land-use change and management over the period will amount to 16 percent of current annual emissions.[212] A scenario in which restoration and protection measures are implemented to maintain ecosystem functions would result in 400 million ha more natural land compared with the baseline scenario, one-third of the projected global biodiversity loss would be prevented, and an additional 83 Gt of carbon would be stored in soils and vegetation, equivalent to more than seven years of current global emissions. On the other hand, limitations on land availability for agriculture would lead to increases in food prices.[235]

To be successful, restoration programmes require accurate and systematic designing, planning and monitoring and a combination of multiple balanced actions on the ground. Trees can play a significant role, but simply planting trees on degraded lands (especially in monocultures) is insufficient and a misconception of forest restoration. FLR goes beyond simply establishing forest cover, involving the restoration of whole landscapes to meet present and future needs and offering multiple benefits and land uses over time.[213]

Peatlands. GHG emissions from peatlands – such as after they are drained, or when they burn – are estimated to constitute about 5 percent of the global CO_2 emissions caused by human activities.[214] Dry, hot and windy weather conditions, which are already a reality in many regions,[215] are leading to long-lasting peatland fires, even along the Arctic Circle.[216] Declining

rainfall, the thawing of permafrost and reduced glacier discharge combined with other complex phenomena that increase peat exposure to oxygen are threatening to turn an increasing area of peatland from GHG sinks to sources.

Smouldering peatland fires draw attention, but the draining of peatlands for cropping, grazing, forestry, energy and other uses is a long-term challenge. Drained peatlands continue to emit GHGs (and ecosystem services continue to decline) until they are rewetted. With peatland mapping and assessment advancing, an increasing number of countries are becoming aware of their depleting peatlands – and their ongoing emissions. Protecting peatlands from drainage, and restoring peatlands, have become priorities for many of the estimated 180 countries with peatlands,[217] and knowledge and experience in peatland restoration have been accumulating since at least the 1970s.[218] Improving peatland management is needed not only to safeguard carbon and reduce fire risk but also to protect coastal and riverine areas from subsidence, ensure flood protection and maintain water filtration services and biodiversity. The cost of peatland restoration is likely to be considerably lower than the estimated local and regional economic benefits, particularly in terms of human health due to reduced haze.[219]

Fire contributes more than 5 percent of greenhouse-gas emissions from agriculture, forestry and other land use. Integrated fire management is much less costly than firefighting

Biomass fires make a significant contribution to GHG emissions, representing more than 5 percent of total emissions from agriculture, forestry and other land use (according to recent unpublished FAO estimates). New estimates using FAOSTAT data indicate that GHG emissions due to biomass fire are roughly 30 percent higher than previously thought.[220] The amount of money spent each year globally on fire management has been increasing, with the bulk in fire suppression: in the United States of America, for example, firefighting expenditure by federal agencies has increased from about USD 240 million in 1985 to USD 2.27 billion in 2020, a nearly tenfold increase.[221] In Canada, the annual national cost of wildland fire protection (i.e. real increases in suppression costs and not the fixed costs to maintain firefighting personnel and programme management) have risen by about CAD 150 million per decade since data collection started in 1970.[222] Few countries have assessed the overall economic burden of wildfire. An exception is the United States of America, where the annualized economic burden (all costs and impacts) of wildfire has been estimated at USD 71.1 billion to USD 348 billion (2016 dollars).[223]

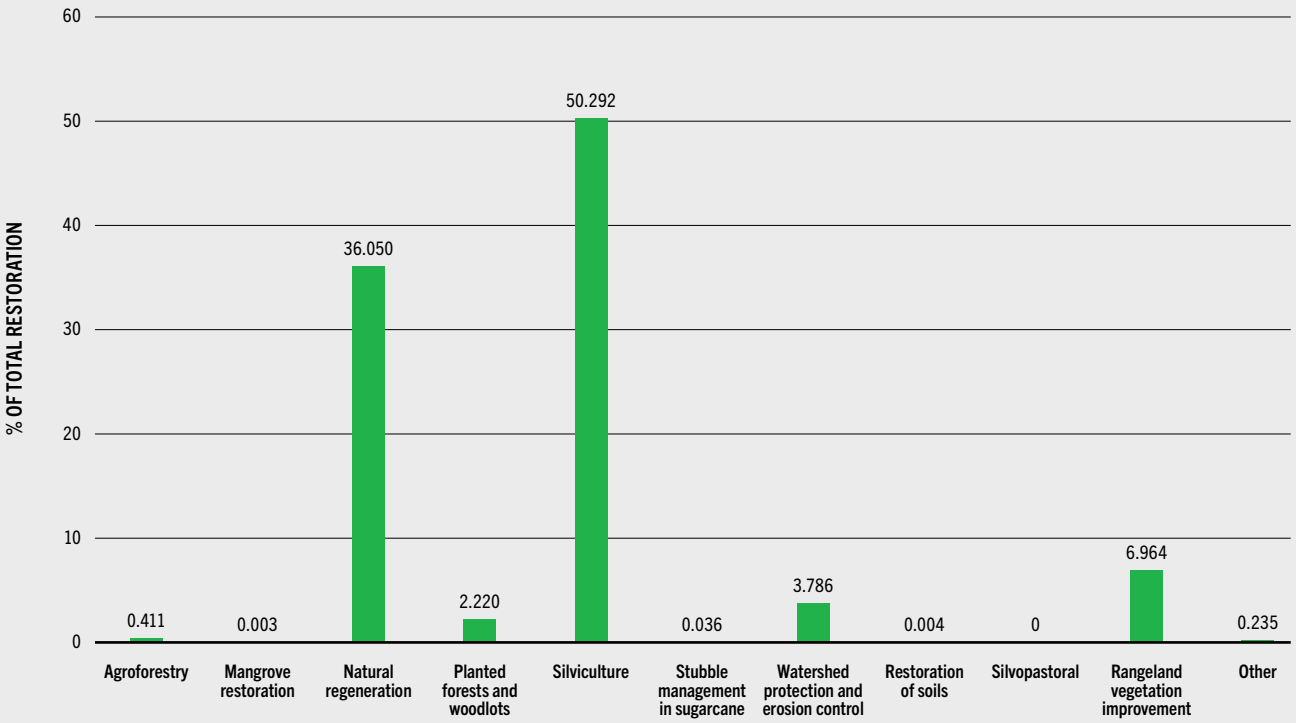
Integrated fire management is widely accepted as an appropriate approach for ensuring that all aspects are considered in fire management planning and decision-making and can help reduce the overall cost burden of fire, especially by reducing the need for wildfire suppression and restoration.[224] A recent study in the European Alpine region estimated the total direct cost of firefighting and post-fire management (excluding prevention measures) at around EUR 75 million per year; conversely, integrated fire management measures including prevention and suppression would cost around EUR 10 million per year. Ecosystem restoration is an important component of integrated fire management and can support the mitigation and prevention of future wildfires.

Restoration can generate substantial economic benefits, potentially yielding USD 7–30 for every USD 1 invested; the restoration of 4 million ha of degraded land in the Sahara and the Sahel created more than 335 000 jobs

Implementing restoration implies investment. For example, the investment required to achieve the Bonn Challenge (the restoration of 350 million ha by 2030) is estimated at more than USD 36 billion annually; the estimated cost of achieving land degradation neutrality globally is USD 318 billion per year between 2015 and 2030.[225]

Despite the attention that restoration is receiving globally, of the USD 14.6 trillion announced by the world's 50 largest economies in fiscal spending as part of the COVID-19 recovery policies and

FIGURE 9 THE RELATIVE PROPORTIONS OF DIFFERENT RESTORATION INTERVENTION TYPES IN BRAZIL, EL SALVADOR, MEXICO (QUINTANA ROO STATE), RWANDA AND THE UNITED STATES OF AMERICA, AS OF 2018



SOURCE: Dave, R., Saint-Laurent, C., Murray, L., Antunes Daldegan, G., Brouwer, R., de Mattos Scaramuzza, C.A., Raes, L. *et al.* 2019. *Second Bonn Challenge progress report – Application of the Barometer in 2018*. © International Union for Conservation of Nature.
https://doi.org/10.2305/IUCN.CH.2019.06.en

stimulus plans, only about 2.5 percent is for green initiatives (which include nature-based solutions and green research and development).[226] Only 3 percent of overall recovery spending is considered positive for natural capital and up to 17 percent could affect it negatively.[227] This is a missed opportunity: restoration can provide some of the highest returns in the form of climate and environmental benefits, jobs and economic growth[228] while also increasing land productivity. For example, it has been estimated that achieving the Bonn Challenge could take an additional 13–26 Gt of GHGs out of the atmosphere,[229] delivering a net benefit of USD 0.7–9 trillion and USD 7–30 for every USD 1 invested.[230] Roe *et al.* (2021) estimated that the restoration of degraded land through afforestation and reforestation could cost-effectively take 0.9–1.5 $GtCO_2e$ per year out of the atmosphere between 2020 and 2050 (see Table 4).[231]

Investments in FLR can generate considerable employment. For example, FLR actions created 354 000 short- and long-term jobs in five countries – Brazil, El Salvador, Mexico, Rwanda and the United States of America – as of 2018;[232] these five countries have collectively committed to restoring 30.7 million ha of degraded land by 2030, mostly through forest-related activities (Figure 9).[233]

Dryland degradation has been valued at USD 6.3 trillion to USD 10.6 trillion per year, and 50 million people could be displaced because of it

TABLE 5 COST DATA RETRIEVED FROM THE LITERATURE ON FOREST RESTORATION IN TROPICAL AND SUBTROPICAL COUNTRIES (23 STUDIES)

Intervention	Cost category	Cost range (USD/ha)
Assisted natural regeneration	Establishment Annual maintenance (years 1–5)	12–3 880 2–213
Agroforestry	Establishment (year 1) Annual maintenance (years 1–5)	125–1 240 5–720
Planted forests (for restoration)	Establishment (year 1) Annual maintenance (years 1–5)	105–25 830 167–2 421
Planted forests (commercial/monoculture plantations)	Establishment (year 1) Annual maintenance (years 1–5)	34–6 888 43–150

SOURCE: Bodin, B., Garavaglia, V., Pingault, N., Ding, H., Wilson, S., Meybeck, A., Gitz, V. *et al.* 2021. A standard framework for assessing the costs and benefits of restoration: introducing The Economics of Ecosystem Restoration. *Restoration Ecology*. https://doi.org/10.1111/rec.13515

in the next ten years.[234] Eleven sub-Saharan GGW member countries (Burkina Faso, Chad, Djibouti, Eritrea, Ethiopia, Mali, Mauritania, the Niger, Nigeria, Senegal and Sudan) have conducted land restoration and sustainable land management activities in the Sahara and the Sahel with the aim of increasing adaptation, mitigation and resilience to climate change, combating desertification, conserving biodiversity and ensuring sustainable development. When accounting for measures strictly within GGW intervention zones, 4 million ha of degraded land has been restored under the programme, generating approximately USD 90 million in revenue for rural people between 2007 and 2020 and creating more than 335 000 jobs, mainly in the implementation of restoration activities and the production and sale of NWFPs.[235]

Only a few long-term examples of successful FLR are available on how to implement the concept's broadly accepted principles[236] in practice. Moreover, there is a lack of systemization of information on FLR costs and benefits.[237,238,239] A literature review of forest restoration costs in tropical and subtropical countries across a range of restoration interventions retrieved 61 relevant studies that provided restoration cost estimates in specific countries.[240] Of these, 23 contained sufficiently robust data to allow the calculation of costs per unit area per year (Table 5). A collaborative international effort, The Economics of Ecosystem Restoration, is underway to obtain more data for economic analyses of landscape restoration to help in prioritizing investment in this process.[241]

In the absence of robust systematized cost–benefit data, restoring degraded ecosystems may be perceived as a costly or not-cost-efficient approach[242] instead of an investment that can generate tangible returns in the future (as well as increase land productivity). Moreover, restoration comprises a wide suite of potential interventions, the upfront costs of which can vary enormously; "active" restoration can cost up to ten times more than natural regeneration approaches[243] but may be needed where there is low site resilience;[244] Box 10 presents an example in which an assisted natural regeneration approach cost about half as much as a more active approach such as tree-planting. The best restoration approach in a given situation depends on various economic, social and environmental factors. Underestimating the benefits and costs of restoration can increase the perceived investment risk. This is especially true in highly degraded landscapes, where the costs are usually considered too high and the direct economic benefits insufficiently tangible to attract investment.

An analysis of 225 case studies in respect to benefits and 94 case studies in respect to costs showed that, even under a worst-case financial scenario, investing in restoration would return a financial profit in six of the nine ecosystem types assessed (Figure 10).[245] Under a best-case

BOX 10 USING ASSISTED NATURAL REGENERATION TO RESTORE A WATERSHED IN THE PHILIPPINES

An assisted natural regeneration (ANR) project in the Danao municipality of Bohol, the Philippines, was implemented with the aim of restoring a highly degraded and deforested watershed area. Initially, considerable effort was required to encourage local stakeholders and authorities to change from conventional tree-planting approaches, although, at USD 579 per ha, the cost of ANR was almost half that of a conventional tree-planting approach in the area (USD 1 048 per ha). The cost is in line with indicative costs for ANR elsewhere in the tropics, at an average of USD 257 for direct establishment costs per ha in year 1 and annual maintenance and monitoring costs for the subsequent five years of up to USD 213 per ha. In Bohol, ANR interventions included establishing firebreaks, employing community members to conduct fire patrols, staking and protecting naturally regenerated seedlings and saplings, reducing competition from grasses by weeding and pressing, and controlling grazing and woodfuel-gathering. Farmers planted food crops in firebreaks to provide financial benefits during restoration. Observable changes in biodiversity were evident in grassland areas within 18 months, and tourism prospects also increased.

SOURCE: Shono, K., Chazdon, R., Bodin, B., Wilson, S. & Durst, P. 2021. Assisted natural regeneration: harnessing nature for restoration. *Unasylva*, 71(252): 71–81.

scenario, restoration would generate positive benefit–cost ratios in all the ecosystem types considered. According to the analysis, tropical forest ecosystems offer among the best value for restoration investment in absolute terms (i.e. based on net present values and at social discount rates of 2 percent and 8 percent). Nevertheless, more data are needed to fully assess the costs and benefits of FLR policies and action and to enable cost-effectiveness and cost–benefit analyses and thereby help unlock and adequately allocate investment;[246] increasingly, tools exist to help in maximizing the cost-effectiveness of FLR interventions (Box 11).

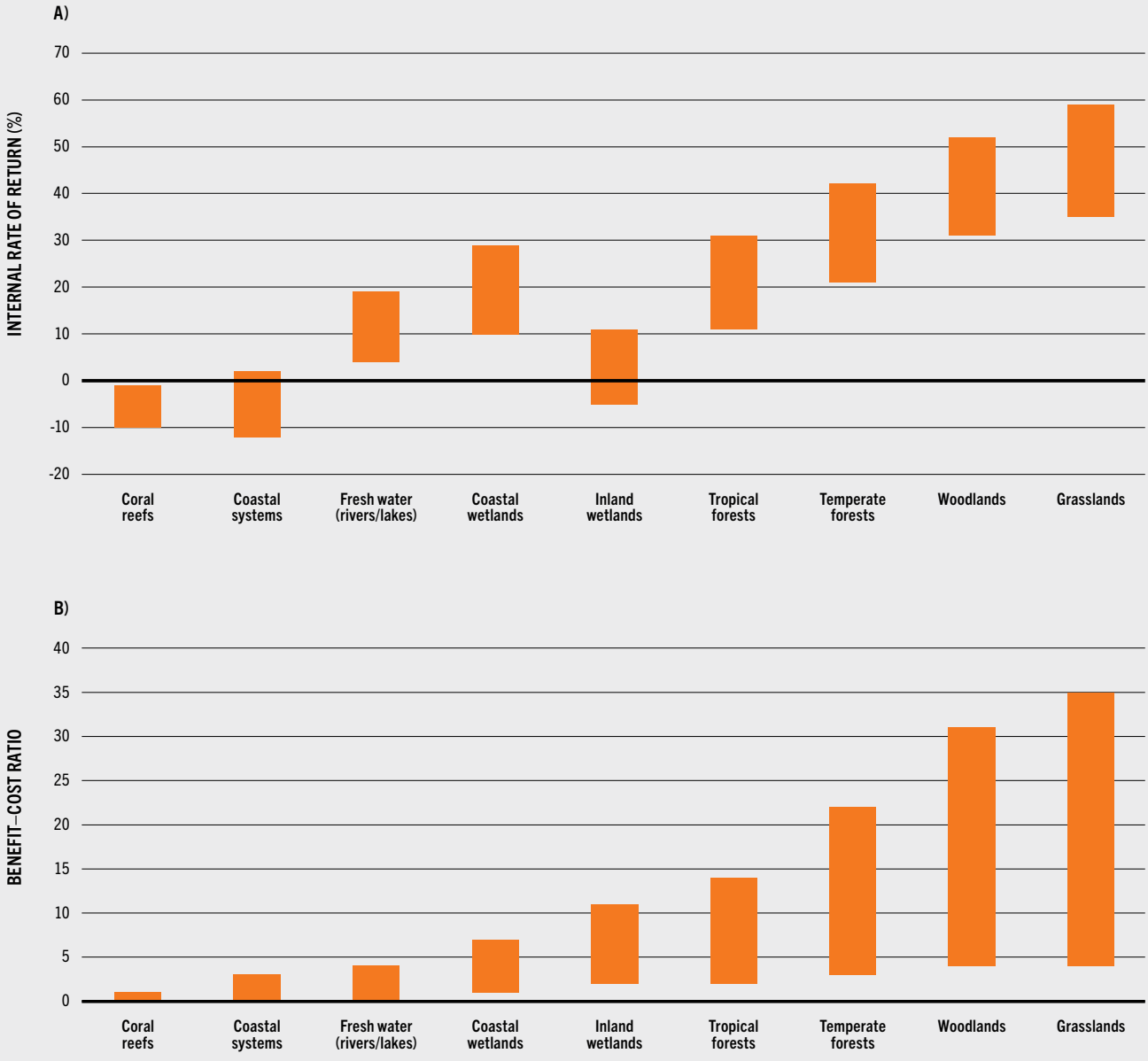
Agroforestry increases biodiversity and carbon in landscapes and can increase smallholder income and resilience but requires incentives to cover risks and upfront costs

Agroforestry is a land-use system that involves the use of perennial woody species with agricultural crops or livestock in a given space and over a given period. Forty-three percent of all agricultural land globally – more than 1 billion ha – has at least 10 percent tree cover.[250] The components of agroforestry (animals, crops and trees) can be combined in a wide range of production processes. The three main types of agroforestry system are: (1) agrosilvicultural (trees combined with crops); (2) silvopastoral (trees combined with animals); and (3) agrosilvopastoral (trees, animals and crops).

As an integrated agrifood system, agroforestry has the potential to advance global food security by increasing crop yield and resilience, providing ecosystem services, addressing land degradation and improving livelihood resilience.[251] Of the 2.2 billion ha of degraded land identified as potentially available for restoration worldwide, 1.5 billion ha is considered best-suited for mosaic restoration in which forests and trees are combined with other land uses such as agroforestry, smallholder agriculture and settlements.[252] The strategic establishment of trees on degraded land can increase agricultural productivity and the provision of ecosystem services, such as improved soil nutrient- and water-holding capacity and pest and weed management.[253,254]

It is estimated that agroforestry systems can contain 50–80 percent of the diversity of natural »

FIGURE 10 INTERNAL RATES OF RETURN (A) AND BENEFIT–COST RATIO (B) FOR RESTORATION IN NINE MAJOR BIOMES



NOTE: Based on 316 case studies over 20 years with a management cost component of up to 5 percent of the capital cost.
SOURCE: De Groot, R.S., Blignaut, J., Van Der Ploeg, S., Aronson, J., Elmqvist, T. & Farley, J. 2013. Benefits of investing in ecosystem restoration. *Conservation Biology*, 27(6): 1286–1293. https://doi.org/10.1111/cobi.12158

BOX 11 SPATIAL PLANNING OPTIMIZATION FOR THE COST-EFFECTIVENESS OF FOREST AND LANDSCAPE RESTORATION

Increasingly, spatial planning tools are available to maximize the benefits of restoration interventions and minimize the negative impacts of land-use decisions. The Restoration Opportunities Assessment Methodology,[247] developed by the International Union for Conservation of Nature and the World Resources Institute, is a flexible cost-effective framework that can be used to identify priority areas and restoration interventions at the national and subnational levels. The WePlan-Forests platform,[248] created by the International Institute for Sustainability and the Secretariat of the Convention on Biological Diversity, helps countries identify where forest and landscape restoration can achieve the greatest biodiversity and climate benefits; quantify trade-offs among multiple objectives of restoration; and fully harness the potential of natural regeneration as a cost-effective restoration strategy. A study on the use of WePlan-Forests in six pilot countries integrated spatially explicit estimates of where natural regeneration is possible with a model of establishment and opportunity costs to create new estimates of forest restoration costs; it demonstrated that accounting for natural regeneration in addition to active regeneration could reduce the establishment costs of forest restoration by 51–65 percent and create billions of US dollars in savings.[249]

» forests and can have 60 percent higher mean taxa richness than forests (consisting of both forest and non-forest species).[255] This higher biodiversity includes above- and below-ground flora and fauna species, many of which (such as pollinators, soil organisms and mycorrhizae) can increase agricultural productivity. A global meta-analysis found that restored agroecosystems, such as agroforestry systems, increase overall species diversity by an average of 68 percent and the supply of ecosystem services by 42 percent.[256] This is particularly significant for soil health, as noted in another recent meta-analysis, which found that agroforestry contributes to boosting ecosystem services, leading to a 50 percent reduction in soil erosion rates, a 21 percent increase in soil carbon storage, and a 46 percent increase in soil nitrogen availability to crops.[257]

The measurement of tree cover on agricultural land can be used to estimate the extent of agroforestry and assess the benefits of agroforestry systems, particularly in terms of carbon sequestration. In a global analysis, remote sensing data estimated that tree cover contributed at least 75 percent of the 45.3 GtC on agricultural lands in 2010.[258] Tree cover on agricultural land increased by 3.7 percent between 2000 and 2010, which increased carbon storage by more than 2 GtC.[259]

Given the potential of agroforestry to help mitigate and adapt to climate change, 40 percent of non-Annex I countries under the UNFCCC propose this land use as a solution in their NDCs, with the measure embraced most widely in Africa (contained in 71 percent of NDCs), followed by the Americas (34 percent of NDCs), Asia (21 percent) and Oceania (7 percent); 50 percent of the 73 developing countries with REDD+ strategies have identified agroforestry as a way to combat forest decline.[260] The COVID-19 pandemic has further highlighted the importance of diversified, resilient, localized production systems for maintaining animal, human and ecological health.

The land-equivalent ratio, defined as the ratio of the area under sole cropping to the area under intercropping needed to give equal amounts of yield at the same management level, is commonly used for comparing productivity in terms of biomass and other yields. In a study of five agroforestry systems in five European countries, the adoption of agroforestry was shown to increase agronomic productivity by 36–100 percent (i.e. a land-equivalent ratio of 1.36–2.00), depending on crop type, crop arrangement and management, and local conditions.[261] Kuyah (2019) analysed

BOX 12 AN AGROFORESTRY MODEL IN THE BRAZILIAN AMAZON

Farmers in Tomé-Açu in the eastern Amazon in Brazil have developed a farmer-led agroforestry model known as SAFTA, which combines market-oriented agroforestry systems and local agro-industry, adding value to agroforestry products and promoting exports to national and global markets. SAFTA is a transitional agroforestry system that involves short-term annual crops, medium-term perennial crops and long-term fruit and timber tree species.[274]

In the past, SAFTA has been supported by the federal and state governments, and currently it is supported by local governments (and it has been branded as a means to position its products in local and international markets).[275] Although SAFTA can take various forms, it is usually based on a combination of 1–3 valuable cash crops (e.g. cocoa, cupuaçu, black pepper and açai) and the production of oils, resins and timber.[276]

126 peer-reviewed studies on agroforestry in sub-Saharan Africa and concluded that, on average, agroforestry systems increased crop yield while maintaining the delivery of regulating/maintenance ecosystem services.[262]

Agroforestry is a potential option for maintaining ecological balance and diversifying rural livelihoods (Box 12).[263] To date, however, it has been promoted primarily for subsistence, and many of its benefits have not been adequately quantified. The distributional ranges of both costs and benefits are highly variable, even within individual practices and systems.

Agroforestry is a longer-term investment than conventional agriculture, requiring longer profit forecasts and planning;[264,265] it can also incur high establishment and maintenance costs, sometimes generating net losses in the first few years.[266] On average, agroforestry sees profitable returns after 3–8 years; for annual cropping systems, this period is normally 1–2 years.

Agroforestry systems are more resilient than conventional agricultural systems to environmental shocks and the effects of climate change, such as severe storms, droughts and floods, due largely to the diversity of benefits they provide.[267] They increase food security and nutrition by serving as safety nets during such shocks,[268] especially when these affect entire communities rather than single households.[269] In an upland area of the Philippines, for example, smallholder farmers who adopted agroforestry had 42–137 percent higher earning capacity and food security than farmers who practised annual monocropping.[270]

Despite the wide-ranging environmental benefits of agroforestry, its adoption and scaling up face challenges, many of which are socio-economic in nature, including labour, gender and farm size.[271] High establishment costs and longer-term returns, access to capital and markets, knowledge and capacity management, and land-tenure insecurity all represent significant barriers to the uptake of agroforestry by farmers. Smallholder producers face trade-offs between alternative land uses, such as monocropping, and need to assess the comparative profitability of a given practice, including whether the practice is culturally appropriate.[272] Although numerous studies have demonstrated the higher productivity of agroforestry systems, many farmers perceive such systems as less productive and thus financially unviable or risky.[273]

The greater uptake of agroforestry requires effective incentives and strategic investments to achieve restoration and improved production objectives, such as providing support for tree establishment, increasing the knowledge and capacity of smallholders and extension professionals in tree-growing, and improving access to markets.[277,278,279]

Government incentives, redesigned agricultural credits and payments for ecosystem services can help address the significant barrier of

limited short-term cashflow. In Peru, a national policy on agroforestry concessions grants land rights to smallholders who encroached forest land before 2011 on the condition that they conserve and sustainably manage forests and establish agroforestry.[280] Given adequate carbon prices and institutional support, payments for carbon sequestration may further incentivize uptake.[304] A study in Ethiopia found that carbon revenue made agroforestry more profitable than monocropping, with carbon revenue being even higher than the net revenue of any monoculture plot when the sequestration rate was high and the price of carbon was at its highest.[281]

Green recovery from the pandemic is an opportunity to increase the restoration effort and thereby create jobs and enable long-term increases in land productivity

As of 2020, nearly two-thirds of the USD 115 billion per year in public funds invested in nature-based solutions is being spent on restoration (forest and peatland restoration, regenerative agriculture, water conservation and natural pollution control systems).[282]

Building back after the COVID-19 pandemic requires not only economic growth but also supporting productive healthy ecosystems (i.e. "green" recovery). Given their potentially high economic returns,[283] the forest sector and nature-based approaches like FLR, peatland rewetting and agroforestry can be effective as part of a green recovery. The potential environmental and socio-economic benefits of FLR and agroforestry are immense, but so too are the challenges of planning and implementing successful interventions on the ground. Thus, considerable effort is needed to compile and share data and knowledge on FLR and agroforestry and how to put these into effect efficiently and to optimize the benefits. ■

3.3 INCREASING SUSTAINABLE FOREST USE, AND BUILDING GREEN VALUE CHAINS, WOULD HELP MEET FUTURE DEMAND FOR MATERIALS AND SUPPORT SUSTAINABLE ECONOMIES

HEADLINES

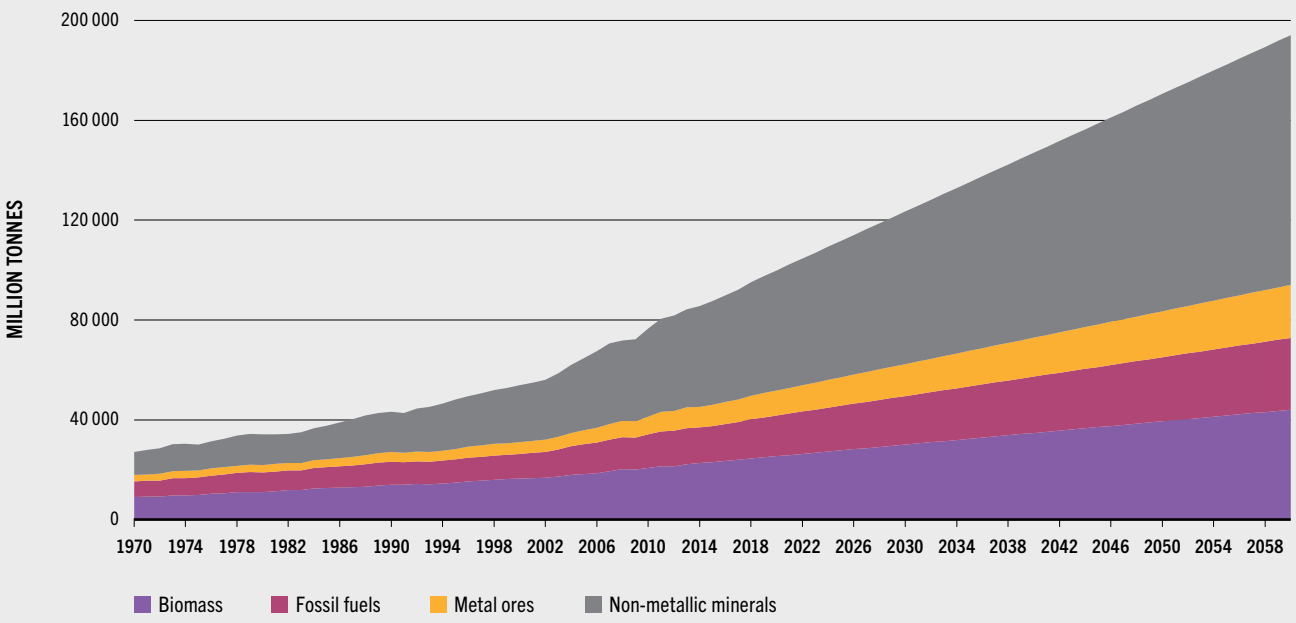
➔ **The world will need more renewable materials.** The global consumption of all natural resources is expected to more than double from 92 billion tonnes per year in 2017 to 190 billion tonnes in 2060, assuming a continuation of current trends.

➔ **An increase in forest area and sustainable forest management could support a green recovery and a transition to carbon-neutral economies.** In construction, for example, replacing a non-wood material with a wood product would, on average, avoid carbon emissions of 0.9 kg of carbon for every 1 kg of carbon in wood.

➔ **There is potential to mobilize forest-based industries to scale up innovative green value chains.** For example, the non-food biobased industries are estimated to grow by 3.3 percent per year to 2030, when output is projected to be worth USD 5 trillion.

The annual global consumption of all natural resources, such as biomass, fossil fuels, metals and minerals, is projected to more than double from 92 billion tonnes in 2017 to 190 billion in 2060 (Figure 11) as a consequence of population growth and increasing affluence.[284] This added demand will strain natural resource systems, including forests.

FIGURE 11 **PROJECTED GLOBAL MATERIAL EXTRACTION, 2015–2060, ASSUMING A CONTINUATION OF CURRENT TRENDS**



SOURCE: Oberle, B., Bringezu, S., Hatfield-Dodds, S., Hellweg, S., Schandl, H. & Clement, J. 2019. *Global resources outlook 2019 – Natural resources for the future we want*. Nairobi, United Nations Environment Programme.

Seventy-five percent of total material demand today is met by non-renewable resources; the remaining 25 percent is supplied by biomass, which comprises organic materials such as food crops, meat and dairy products and a host of forest and other biomass products. Worldwide, biomass extraction increased from 9 billion tonnes in 1970 to 24 billion tonnes in 2017 and is expected to reach 44 billion tonnes by 2060.[285]

The agrifood industry accounts for most of the biomass consumption worldwide. The global harvest of major crops, such as cereals, oil and sugar crops, roots, tubers and pulses, amounts to about 27 percent of the global biomass used for food, fodder, fibre and forest products.[286] The timber and wood-based industry is another key biomass-consuming sector, with world production of roundwood (at 3.91 billion m^3 in 2020) increasing by 12 percent in the last two decades.[287]

Demand for biomass is expected to rise further to meet growing needs for food, energy, housing and other material uses. Demand for forest-based biomass will be driven mainly by construction (with demand in that sector expected to almost triple by 2030) and packaging (with demand expected to double by 2030).[288] Sustainably meeting demand for forest-based biomass will require an increase in resource supply through restoration, reforestation and afforestation on degraded lands and increased resource efficiency. Sustainability also requires efforts to improve manufacturing efficiency and energy flows, promote the cascading use of forest products, change consumption patterns, and facilitate a transition to more circular economies.

When sustainably produced, wood has significant potential to reduce greenhouse-gas emissions from the building and construction sector

Providing housing for a growing and increasingly urbanized population is a major challenge. Globally, an estimated 3 billion people (40 percent of the world population) will need new housing by 2030, which translates into a need for 300 million new dwellings (between 2016 and 2030).[289]

The construction sector, which was responsible for almost 40 percent of energy- and process-related GHG emissions in 2018,[290] will thus pose a major threat to sustainability. Eleven percent of the total emissions of the building and construction sector can be attributed to materials; transitioning to carbon-storing renewable construction materials such as wood, therefore, could be a significant means for mitigating climate change.[291,292]

Product-level studies that estimate the substitution effect underscore the important role that wood buildings can play in decarbonizing the construction sector. A recent literature review concluded that wood has a median substitution factor[h] of 0.9 – in other words, every 1 kg of carbon in wood that replaces a non-wood material in a building system could produce an average emission reduction of about 0.9 kg of carbon.[293] A study in Finland found that, due mainly to the environmental benefits of wood as a construction material, residents of wooden houses have a 12 percent lower carbon footprint (amounting to 950 kg CO_2e per year), on average, than residents of non-wooden houses.[294] Wooden buildings also have positive impacts on the physical, mental and emotional health of occupants.[295] According to a study in Australian workplaces, biophilic designs that incorporate exposure to wood can reduce sick leave and increase the overall well-being of workers, leading to a 5 percent increase in productivity.[296]

h Substitution factors are typically used to express the emissions that would be avoided if a wood-based product is used instead of a product made from another material providing the same function. Thus, a substitution factor of 1 would mean avoiding 1 kg of carbon emissions for every 1 kg of carbon in wood products used in place of non-wood materials. Substitution gains may be counterbalanced by a reduction in forest carbon stock and other leakage effects between regions and need to be further assessed and considered.

The development of "mass timber" construction and associated novel wood-frame multistorey construction practices has led to significant growth in demand for engineered wood products, particularly cross-laminated timber. Although the majority of cross-laminated timber projects are in developed countries, wood construction is poised to gain momentum in other parts of the world, too (Box 13).

The increased use of wood in construction can contribute to economic development in the global South. For example, under one scenario, it has been estimated that the production and primary processing of wood to meet expected demand for housing could contribute up to USD 83 billion to Africa's bioeconomy by 2050 while creating 25 million jobs through the additional forest plantations and processing needed to develop the building materials.[300] Unlocking this potential, however, requires investment to strengthen technological and human capacity.

Wood encouragement policies, which, in developed countries, tend to focus on public procurement for buildings and infrastructure, can support and promote the use of wood in built environments (Box 14).[301]

Unfavourable building codes can inhibit the greater use of wood in multistorey buildings. Recent changes to building codes at the international (e.g. the 2021 International Building Code), national (e.g. Australia) and provincial (e.g. British Columbia, Canada) levels have been introduced to enhance the use of wood in the building construction sector.[302,303]

The World Business Council for Sustainable Development estimates that biomass demand will grow by 8.8 percent per year to 2030 due to the building and construction sector,[304] and greater interest in buildings based on mass timber might further increase demand. Sustainably meeting such heightened demand will require greater resource efficiency (among other things), which is increasingly feasible, such as through off-site construction approaches involving digitally precise designs, prefabrication and the remote assembly of building components.

BOX 13 GABON PROMOTES CROSS-LAMINATED TIMBER BUILDINGS

Gabon created the Gabon Special Economic Zone (GSEZ) in 2010, considered the world's first certified carbon-neutral industrial zone.[297] The zone, which is a joint venture between the Government of Gabon, Olam International and the African Finance Corporation, was developed at a cost of USD 400 million as a platform for establishing wood-processing facilities in Africa. The development of the wood sector, including the sustainable construction of the built environment, is among the governmental priorities identified in Gabon's "Emergent 2025" national strategy to reduce greenhouse-gas emissions, encourage the sustainable use of forest products and tap into emerging markets.[298]

The government also launched an initiative to construct Gabon's first cross-laminated timber building, the Gabon Sovereign Wealth Tower. This project aims to maximize the use of locally sourced wood materials; achieve design excellence for mass-timber-based mixed-use development and zero-carbon construction; anchor the development of mass-timber value chains in sustainable forest management; and enhance the transfer of skills in timber value chains and the construction sector. According to initial calculations, the tower has the potential to remove about 1.5 million kg of carbon dioxide from the atmosphere, a weight equivalent to 36 Boeing 737-800s.[299]

BOX 14 WOOD ENCOURAGEMENT POLICIES

Wood encouragement policies (WEPs) are policies formulated at the national or subnational level to promote the use of wood as a building material – they are in place in (for example) Australia, Canada, France, Germany, Japan, New Zealand and the United States of America. WEPs are designed to support local forest industries, sustainable economic development and climate-change mitigation objectives. Most, but not all, WEPs target public buildings.

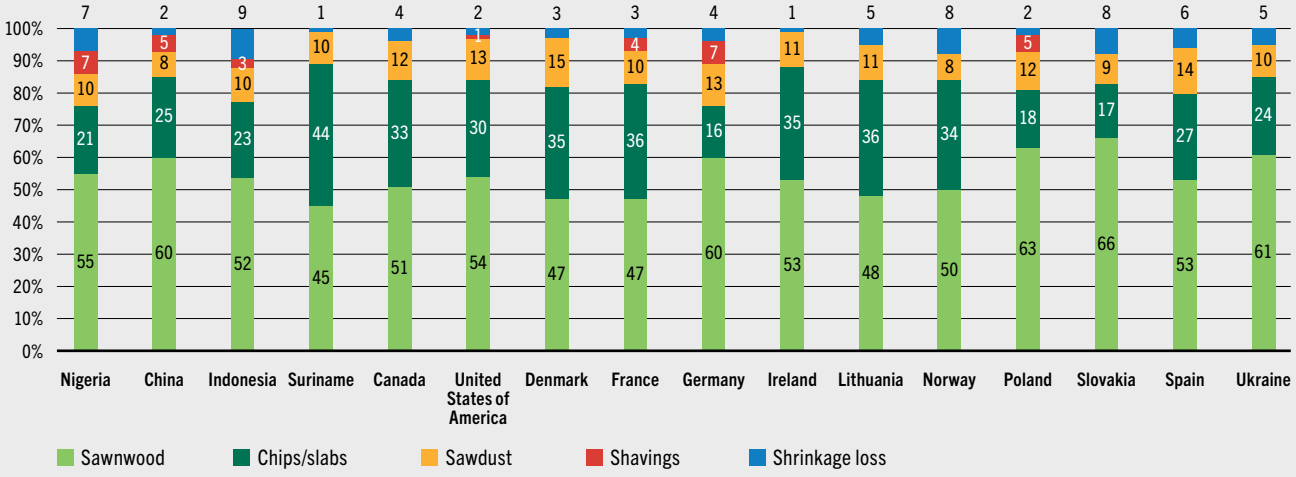
SOURCE: FAO. 2020. *Status of public policies encouraging wood use in construction – An overview.* Draft background paper prepared for the 61st Session of the FAO Advisory Committee on Sustainable Forest-based Industries. Rome.

Improvements in material efficiency can help sustainably meet global wood demand

Minimizing any negative environmental implications of the forecast increase in wood demand requires an increase in efficiency and avoidance of wood loss and waste in harvesting and processing. Improvements in material efficiency are underway. An assessment of efficiency improvements in Canada, for example, found that the rate of harvested wood use increased from 61 percent in 1970 to 83 percent in 2016; moreover, residues from solid-wood processing and pulping processes are increasingly used as biomass fuel to substitute fossil fuels.[305]

Efficiency gains can be amplified through the cascading use of wood raw materials. These can be estimated through "material balances", which approximate material losses by estimating the difference between the quantity of total material consumed in one processing step and the total material produced in the following processing

FIGURE 12 MATERIAL BALANCE IN THE SAWMILLING PROCESS FOR NON-CONIFEROUS SAWNWOOD



SOURCE: FAO, International Tropical Timber Organization & United Nations. 2020. *Forest product conversion factors*. Rome.
https://doi.org/10.4060/ca7952en

step.[i] The path of cascading use and the range of estimated losses provide indications of where and how much efficiency gains might be possible. In the case of sawnwood production, for example, reporting countries indicate that 45–66 percent of the roundwood volume used becomes sawnwood, about one-third becomes chips and slabs, approximately one-tenth becomes sawdust and, in some countries, an additional 2–10 percent becomes shavings (Figure 12).[306] What is not used for any of the above products is considered shrinkage loss, which varies considerably between countries due to (for example) differences in species, the portfolio of products produced, available markets, and technologies.

The percentage of material used for low-value products or lost through shrinkage may be much higher in developing countries with only limited use of modern technology across the harvesting and processing stages and with limited access to markets for the full suite of wood products.

Adding value across the cascade of products could extend material lifespans, reduce original demand for material, and extend carbon storage times and thus enhance the sustainable use of forest products. Wood residues from the industrial processing of roundwood can be a valuable resource if used as feedstock for other products and if ultimately used for energy generation, substituting for less-sustainable energy sources.

Recycling and re-use, which increase the lifespan of products, are another form of cascading use. Paper is one of the most commonly recycled materials globally: the industry has achieved a recovery rate of more than 60 percent in Europe and Northern America, nearly 50 percent in Latin America and the Caribbean and Asia and the Pacific and just under 30 percent in Africa.[307] A recent analysis found that achieving the maximum technical recycling potential of waste wood and paper would increase the wood-use efficiency ratio in the European wood sector by 31 percent, leading to a concomitant reduction in GHG emissions of 52 percent.[308] Thus, while increasing resource efficiency is feasible, regional disparities persist. Capacity development, technological and design

i The cascading use of wood and wood loss can be quantified using forest product conversion factors, which indicate the quantity of one product that can be produced from another and how much loss would be expected during that process.

BOX 15 USE OF WOOD FIBRE IN THE MANUFACTURE OF MEDICAL PRODUCTS

The COVID-19 pandemic has dramatically increased demand for a range of medical products, particularly personal protective equipment such as gowns, masks, surgical drapes and bed sheets, which are typically made of non-woven polypropylene but can also be made with wood fibre. A paper membrane made of highly crystalline cellulose nanofibres can filter virus particles and thus mitigate their spread.[312] Fully compostable and biodegradable medical masks have been developed using wood fibre.[313] Wood fibre can also be used in biobased value chains to manufacture hygiene papers, hand sanitizers, soaps, toothpastes and diapers, and there have been advances in the development of low-cost wound dressings made of wood-based nanocellulose.[314,315] Demand for health supplements extracted from forests grew dramatically during the pandemic. In the United States of America, for example, sales of herbal dietary supplements for immune health, stress relief and heart health increased by 17.3 percent between 2019 and 2020, to USD 11.3 billion; top-selling supplements contained black cohosh (*Actaea racemosa*), açai (*Euterpe oleracea*), ginseng (*Panax* spp.), *Garcinia gummi-gutta* and mushrooms (*Cordyceps* spp.).[316]

SOURCE: Verkerk, P.J., Hassegawa, M., Van Brusselen, J., Cramm, M., Chen, X., Imparato Maximo, Y., Koç, M. *et al.* 2021. *Forest products in the global bioeconomy.* Rome, FAO. https://doi.org/10.4060/cb7274en

innovation and a conducive policy framework are needed to increase material efficiency globally by improving the technological and social infrastructure.[309]

Biobased industries cater to a wide range of needs with environmentally friendly products and add value to resources

Forests and trees provide renewable raw materials for a host of manufacturing industries that produce a wide range of bioproducts; some (e.g. wooden furniture, pulp and paper, cork, bamboo, rattan, medicinal plants and resins) have been in use for millennia, and others (e.g. wood foam, textile fibres and bioplastics) are the result of recent innovations. Renewable bioproducts allow the substitution of GHG-intensive products.[310]

The non-food biobased industries are estimated to grow at 3.3 percent per year to 2030, when their output is projected to be worth USD 5 trillion.[311] A diverse range of forest-based bioproducts contributes to the global bioeconomy, some of which are described below and in Box 15.

- **A wide array of biochemicals** can be manufactured from biomass, such as adhesives, lubricants, surfactants and emollients. Biochemicals are considered a growth sector, with the global chemicals industry generating an estimated EUR 4.01 trillion in 2020.[317] Significant opportunities lie, for example, in the kraft lignin segment, in which only 1–2 percent of residues are currently converted into higher-value products.[318]
- **Bioplastics** can be produced using lignin and industrial side streams from the pulp-and-paper industry. Bioplastics currently represent only 1 percent of the total volume of plastics produced annually. The current production capacity of second- and third-generation feedstock bioplastics derived from crops and plants not suitable for food or feed (e.g. trees), waste from first-generation feedstock (e.g. bagasse and waste vegetable oil) and algae is estimated at 2.3 million tonnes; production capacity is projected to grow to 4.3 million tonnes by 2022.[319]
- The production of **manufactured cellulosic textiles** (typically derived from wood or other plant-based material) is projected to rise from 6.4 million tonnes in 2020 to 8.6 million tonnes in 2027.[320] Such wood-based textiles could have a substitution factor as high as 2.8.[321] According to a recent scenario-based estimate, global roundwood production would increase by 81 million m^3 by 2040 if wood-based fibre met 30 percent of total textile fibre demand.[322]

BOX 16 THE POTENTIAL ROLE OF BIOMASS IN ACHIEVING NET-ZERO EMISSIONS BY 2050

The International Energy Agency (IEA) (2021) sets out a roadmap for the global energy sector in which modern bioenergy, especially woodfuels, would play a key role in achieving net-zero emissions – modern bioenergy use would increase by around 60 percent between 2020 and 2050 alongside a shift away from the traditional use of biomass.[332] Under the IEA's net-zero-emissions-by-2050 scenario, the land area for dedicated biomass plantations would need to increase from 330 million ha in 2020 to 410 million ha in 2050. Increasing biomass production by 60 percent in 30 years to meet bioenergy production goals will require a comprehensive set of policies, strategies, regulations, management measures and financial resources to ensure that such additional biomass production is sustainable and does not cause economic, social or environmental harm, such as the loss of soil quality and biodiversity.

Forest-based bioenergy needs to become more efficient, cleaner and greener

Energy production is the major use of wood globally; more than 2 billion people will still rely on the traditional use of woodfuel and other types of biomass energy for cooking by the end of the present decade, especially in the world's most impoverished regions.[323]

In some areas, demand for woodfuels, including fuelwood and charcoal, exceeds the sustainable supply capacity of forests and trees, leading to forest degradation and loss. According to one estimate, 27–34 percent of woodfuel extraction in pantropical regions is unsustainable, and approximately 275 million people live in woodfuel-depletion hotspots in South Asia and East Africa.[324] The gap between demand and sustainable supply can be bridged by the restoration of degraded forests, the establishment of fast-growing tree plantations, improving the use of residues from wood harvesting and processing, and the recovery of post-consumer wood through its cascading use within a more circular economic framework. Plantations can reduce pressure on natural forests and woodlands[325] near major charcoal demand centres, such as urban areas in sub-Saharan Africa.[326] A recent technical and economic feasibility study on industrial charcoal production in the Congo estimated a 10.7 percent financial return on investment based on the establishment of tree plantations, the additional production of briquettes using dust created by charcoal production, and the use of clean, efficient charcoal kilns.[327]

National woodfuel strategies are important for coordinating actions across government agencies and ensuring that interventions produce positive economic, social and environmental impacts. Malawi's National Charcoal Strategy (2017–2027), for example, presents a multisectoral framework for addressing problems in charcoal production and demand in the near, medium and long terms, aligning with other national strategies and policies that promote broad objectives aimed at reducing deforestation, forest degradation and dependence on solid biomass fuels.[328]

Modern applications of woodfuels typically include the heating of residential and commercial buildings (as either standalone or district heating facilities) and use in industrial processes; electricity generation and the cogeneration of heat and power (by the direct burning of woodfuel or co-firing with coal); and the production of liquid fuels for the transport sector.[329] There is considerable interest in increasing the use of bioenergy to help achieve net-zero emissions in the energy sector (Box 16). Burning forest biomass returns to the atmosphere only carbon that plants have absorbed as they have grown; burning fossil fuels releases carbon that has been stored in the ground for millions of years. Nevertheless, there are environmental concerns about the further use of wood biomass for bioenergy production associated

BOX 17 WOODFUEL AND EMPLOYMENT IN NIGERIA

In many developing countries, the transition to improved energy access and modern renewables may have implications for livelihoods. In Nigeria, where biomass is the largest source of total primary energy supply, about 40 million people (i.e. one-fifth of the population) are engaged directly in fuelwood collection and charcoal production, which provides an estimated 530 000 full-time equivalent direct jobs. An additional 200 000 people – mostly also full-time – provide transport services for retail and wholesale trade.[334] Large numbers of livelihoods in other sub-Saharan African countries also depend on the fuelwood and charcoal economies.[335]

with GHG emissions, soil-quality degradation and biodiversity loss. Therefore, there is a need for environmental, economic and social sustainability in bioenergy production, which can be assessed through a set of multicriteria indicators, and life-cycle assessment can be used to explore environmental performance.[330] Although the full impact of woodfuel on climate change is disputed,[331] there is little disagreement that benefits can be maximized by applying sustainable forest management practices and increasing the operational efficiencies of combined-heat-and-power plants and biorefineries.

Raw-material demand for energy can be reduced by increasing efficiency in the woodfuel conversion and utilization processes. This can be achieved by improving the properties of wood residues through the production of wood pellets and briquettes; increasing woodfuel processing efficiency with improved charcoal production kilns; improving woodstove thermal efficiency; and increasing access to modern energy forms, such as electricity (including renewable forms, such as solar and wind), liquefied petroleum gas and biogas from organic wastes. Various innovative efforts – such as those in the Venture Catalyst portfolio of the Clean Cooking Alliance[333] – are underway to encourage the clean and efficient burning of woodfuels and reduce woodfuel demand. In some countries, transitioning to modern woodfuels could have profound livelihood implications (Box 17). ■

KENYA
A worker moving pieces of wood coming from trees belonging to the Nyandarua Tree Growers Association at the Waka Sawmill.
©FAO/Luis Tato

CHAPTER 4
VIABLE OPTIONS EXIST FOR SCALING UP INVESTMENT IN THE FOREST PATHWAYS – WITH POTENTIALLY CONSIDERABLE BENEFITS

HEADLINES

➔ **Forest investment is well below what is required.** Financing for the forest pathways needs to increase fourfold by 2050 if the world is to meet its climate, biodiversity and land degradation targets.

➔ **All sources of funding – domestic government, private and official development assistance – will need to be tapped, and new approaches are emerging.** For example, ecological fiscal transfers, implemented in only a few countries to date, amount to 20 times the global official development assistance for forestry.

➔ **Redirecting socially and environmentally harmful support, and improving the regulatory environment, could release considerable funding for the forest pathways.** For example, repurposing agricultural subsidies – currently almost USD 540 billion per year – to include forestry and agroforestry could help avoid the harmful impacts embodied in 86 percent of such subsidies.

➔ **Getting finance to small-scale producers will be essential for implementing the pathways.** Small producers received less than 1.7 percent of climate finance in 2019, and the situation does not appear to have improved since. New finance solutions and investment modalities that suit small-scale producers and reduce inequalities need to be shared and scaled up.

Increasing investment in the three forest pathways described in Chapter 3 requires an assessment of current financial flows, the accurate tracking of how such funds have been allocated, and identifying what must change to both redirect existing money and attract new investment. Financial sources for scaling up implementation of the forest pathways comprise international and domestic public and private resources that can operate separately or in a mix, for example using public money to catalyse private sector investment (Figure 13).

This chapter examines existing public and private financial flows for green recovery and growth (noting that, with the exception of recovery data, all figures are pre-COVID-19 estimates); considers the funding required to meet key global targets; provides examples of how both public institutions and the private sector are increasing support for the three pathways; canvasses instruments that can be used to support small producers in implementation; and suggests options for mobilizing the additional finance needed to transition towards a greener and more sustainable future. As shown in this chapter, evidence indicates at least five high-potential areas for scaling up implementation of the forest pathways – (1) greening public domestic finance; (2) making climate finance work for forest-based approaches; (3) greening financial markets with regulatory and supervisory tools, with the clear positioning of forest-based approaches; (4) developing pipelines of investment-grade projects; and (5) supporting investment in value-added wood processing in countries of origin. ■

4.1 DESPITE THE HIGH VALUE OF FORESTS AND TREES, INVESTMENT IN THEM IS LOW. CLIMATE FINANCE FOR FORESTRY IS INCREASING FROM A LOW BASE

Accurately tracking flows of forest finance is important for efficient resource allocation. At present, however, not all such flows are monitored, which can lead to poor financing decisions. Existing estimates suggest that investment in forests and trees is low relative to the huge value they have for individuals, communities and societies, but there is scope for changing this.

Climate finance flows to forestry almost doubled between 2015 and 2019, but domestic public expenditure on forestry far exceeds it, even in some low-income countries

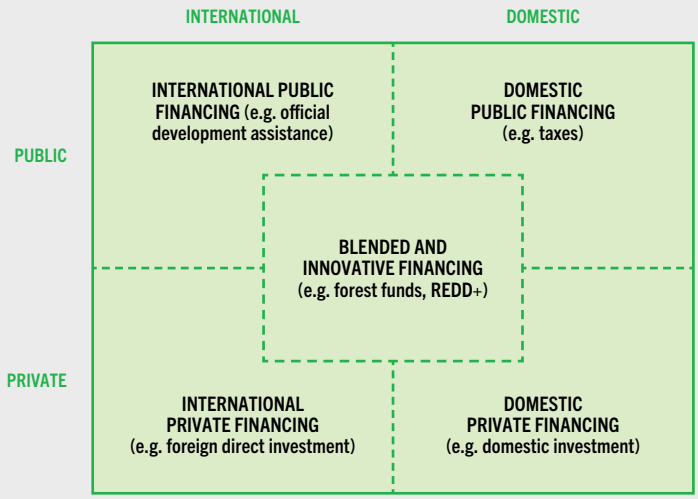
Climate finance data provided by the Organisation for Economic Co-operation and Development (OECD) Development Assistance Committee (DAC) is the most comprehensive and consistent data with global coverage that specifically identifies the forest sector. Data reported by both DAC and non-DAC members can be extracted from the OECD DAC External Development Finance Statistics database,[336] which includes official development assistance (ODA), other official flows, private grants and private amounts mobilized. Figure 14 summarizes climate finance flows to forestry compared with other sectors – those to forestry almost doubled between 2015 and 2019 but are still below the level of investment needed. There has been a substantial increase in climate-related development finance for all sectors since 2000, but little of this has been directed towards forestry, with the share of climate finance channelled to forestry not exceeding 4 percent of the total between 2009 and 2019 (Figure 15). Pledges made at the 2021 UN Conference on Climate Change may boost funding for forests (see Box 24).

National public expenditure on forests far exceeds that obtained via ODA, even in some low-income countries. For example, an analysis of public expenditure on forestry in 13 sub-Saharan African countries in 2016–2018 (Figure 16) showed that, on average, national governments spent 3.5 times as much on forestry as the amount received as ODA for this purpose. National public forestry expenditure exceeded forestry ODA in all 13 countries except Burkina Faso, Mali, Malawi and Rwanda.[j] Therefore, policymakers should focus attention more (or at least as much) on domestic finance than on international funding.

A global analysis by Whiteman *et al.* (2015) on domestic forest-sector expenditure reached similar conclusions, finding that governments spent approximately USD 38 billion on forest-related activities in 2010.[337] The relative importance of domestic public finance for forestry compared with other sources has also been observed for biodiversity finance[338] and in a recent compilation of studies on the finance available to support nature-based solutions.[339]

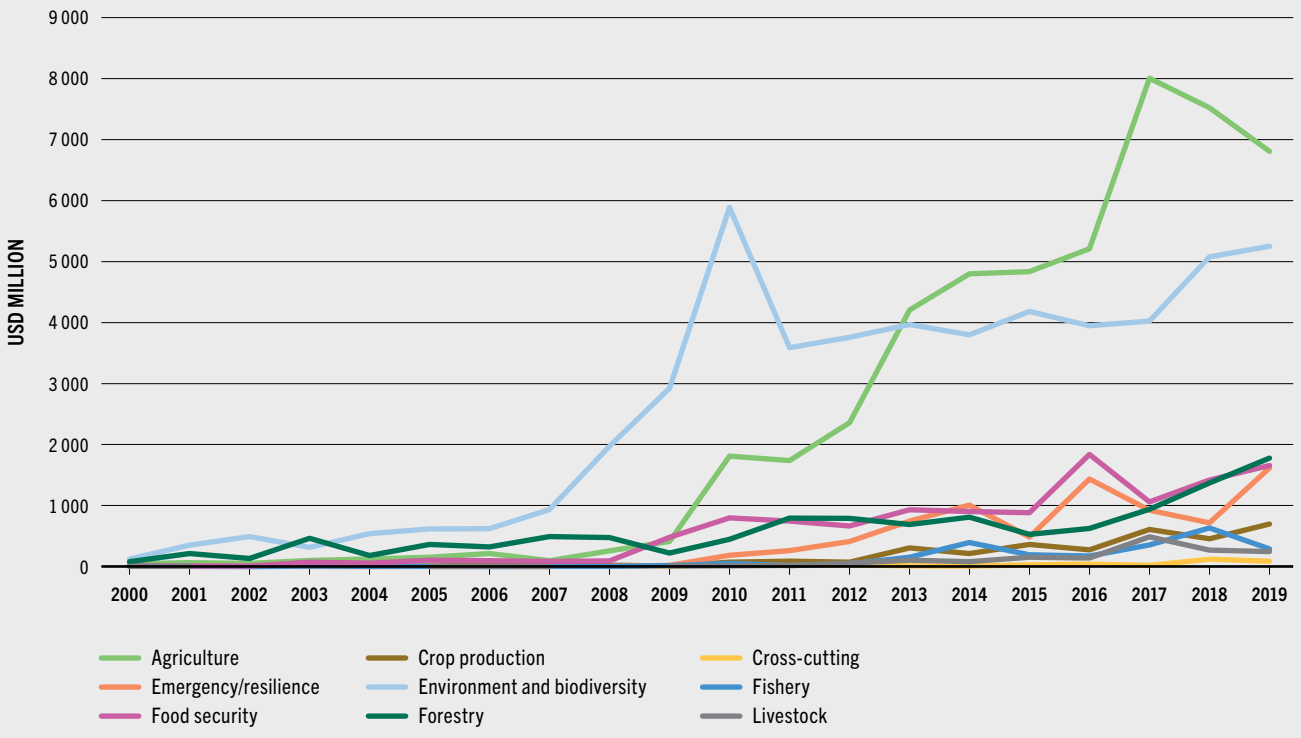
j Nevertheless, assessing and tracking finance allocations for forests in support of green growth is challenging because of a lack of commonly agreed definitions of what constitutes finance for the three forest pathways – forest-related approaches may be included in estimates of "green", "sustainable", biodiversity", "nature-based solutions", "climate-based solutions" and "SFM" finance; and data on domestic public finance and private finance are notoriously difficult to collect and assess.

FIGURE 13 DIVERSITY OF FOREST FINANCE SOURCES


INTERNATIONAL
DOMESTIC
PUBLIC
PRIVATE
INTERNATIONAL PUBLIC FINANCING (e.g. official development assistance)
DOMESTIC PUBLIC FINANCING (e.g. taxes)
BLENDED AND INNOVATIVE FINANCING (e.g. forest funds, REDD+)
INTERNATIONAL PRIVATE FINANCING (e.g. foreign direct investment)
DOMESTIC PRIVATE FINANCING (e.g. domestic investment)

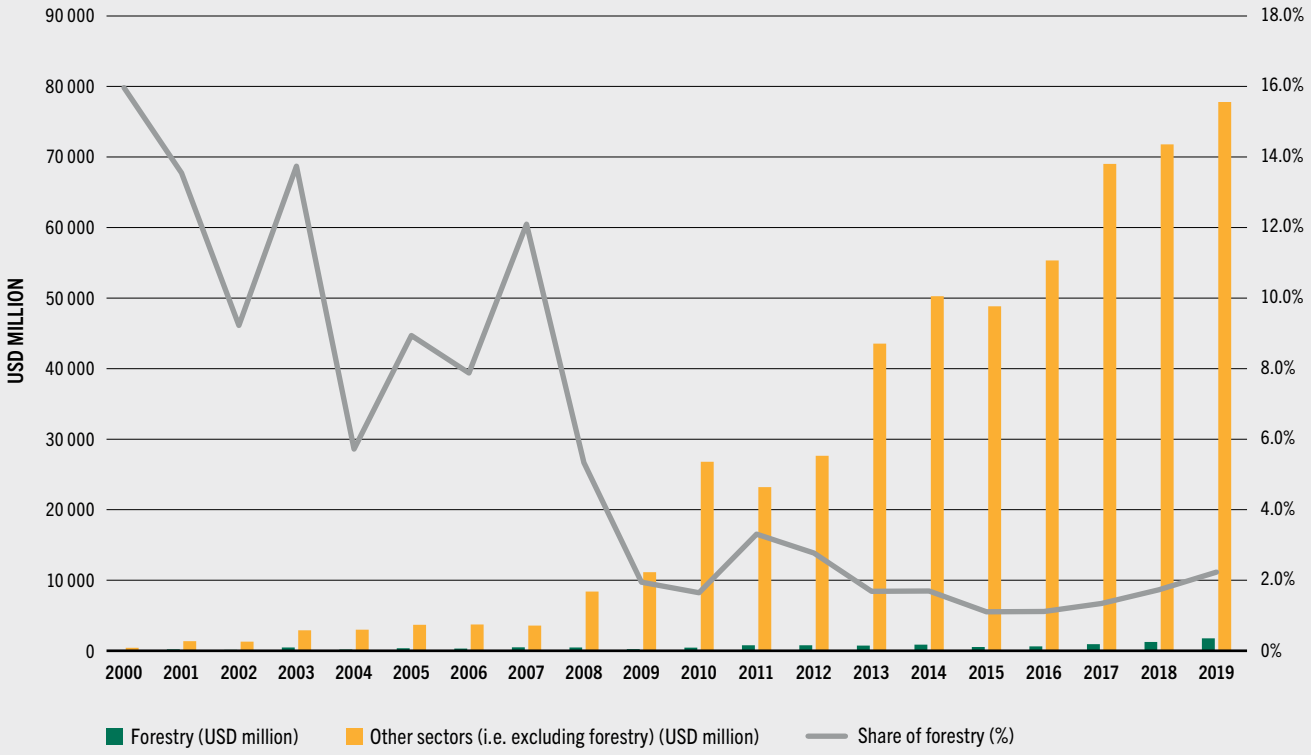
SOURCE: Singer, B. 2016. Financing sustainable forest management in developing countries: the case for a holistic approach. *International Forestry Review*, 18(1): 96–109. https://doi.org/10.1505/146554816818206159

FIGURE 14 ALLOCATIONS OF CLIMATE-RELATED DEVELOPMENT FINANCE TO THE AGRICULTURE, FORESTRY AND OTHER LAND-USE SECTORS



SOURCE: Organisation for Economic Co-operation and Development DAC External Development Finance database, compiled by FAO.

FIGURE 15 CLIMATE FINANCE FOR FORESTRY



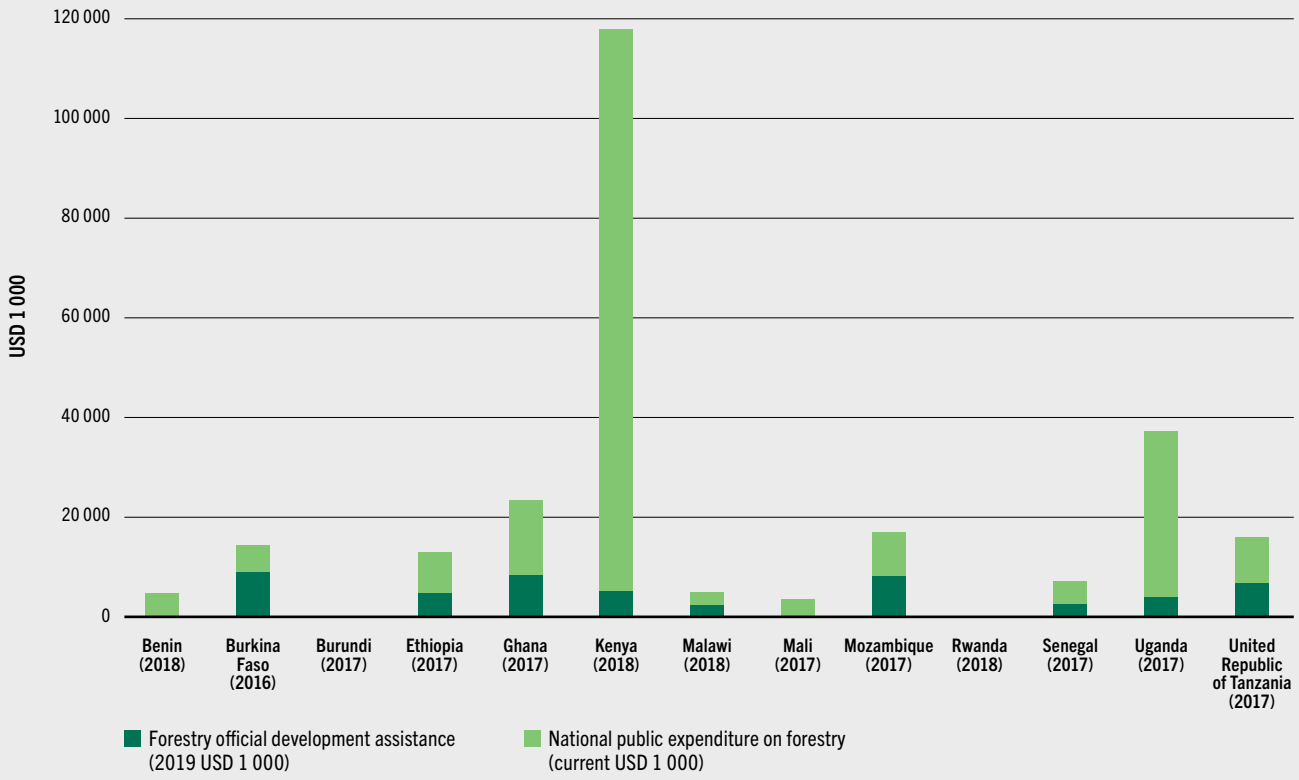
SOURCE: Organisation for Economic Co-operation and Development DAC Climate-related Development Finance database, compiled by FAO.

Few pandemic recovery plans have mobilized significant finance for the forest pathways. Increasing such finance is an important opportunity for green recovery

As of May 2021, total spending on recovering from the COVID-19 pandemic amounted to a massive USD 16.6 trillion in 87 of the world's largest economies, of which USD 2.1 trillion was for long-term economic recovery and USD 420 billion was for green recovery.[340] A recent analysis suggested that most recovery programmes will have a negative impact on green sectors, including forestry (Figure 17).[341] Although, at first glance, European Union countries appear to have achieved a more positive balance, only 11 of the 27 countries integrate forests directly in their national recovery and resilience plans (through a chapter or subchapter), and an average of only 0.77 percent of the total resources indicated in these plans has been allocated to forests across the 27 countries.[342] Two European Union countries – Romania (5.2 percent of the total budget) and Sweden (7.7 percent) – have developed ambitious forest programmes as part of their pandemic recovery plans. Outside the European Union, the Dominican Republic, India, Kenya, Pakistan and Peru have allocated funds for afforestation and reforestation (the restoration pathway), and Argentina and Peru are promoting wood value-added processing and youth employment (the sustainable-use pathway).[343]

It will also be important to increase adaptation finance for forests. The latest (2020) report of

FIGURE 16 PUBLIC EXPENDITURE IN FORESTRY IN 13 SUB-SAHARAN AFRICAN COUNTRIES, AND FORESTRY OFFICIAL DEVELOPMENT ASSISTANCE



NOTE: The Monitoring and Analysing of Food and Agricultural Policies (MAFAP) dataset from which this figure was derived contains public expenditure on forestry in 13 sub-Saharan African countries for the period 2004–2017. Expenditure is allocated based on the source of finance (i.e. international donor or national public). Data were obtained from national institutions and, where possible, the database includes the full budgets of the countries. Expenditure is classified according to MAFAP classification in close coordination with governmental counterparts and national consultants. These expenditure indicators, as computed by the MAFAP, have two main limitations. First, they are extrapolated from direct support to the food and agriculture sector, which includes expenditure by the ministries of agriculture, livestock, fisheries, forestry, environment and other agriculture-specific projects, where available. Therefore, certain expenditure, such as that focusing on natural parks and other environmental transfers unrelated to the agriculture sector, are excluded. Second, data for certain ministries were inaccessible. For more details on public expenditure data coverage and limitations, see Annex 2 of Pernechele, V., Fontes, F., Baborska, R., Nkuingoua, J., Pan, X. & Tuyishime, C. 2021. *Public expenditure on food and agriculture in sub-Saharan Africa*. Rome, FAO. https://doi.org/10.4060/cb4492en
SOURCES: FAO Monitoring and Analysing of Food and Agricultural Policies database and Organisation for Economic Co-operation and Development DAC Climate-related Development Finance database, compiled by FAO.

multilateral development banks (MDBs) on climate finance indicated that about 4 percent of adaptation finance from them is channelled to "other agricultural and ecological resources" (including forests).[344] Knowing that adaptation finance from MDBs was 24 percent of total MDB climate finance in 2020,[345] it is clear that adaptation finance for forests is limited. This matches other recent figures: in 2018, public donor finance for nature-based solutions for adaptation accounted for approximately 0.6 percent of total climate finance flows and 1.5 percent of public climate finance flows.[346] Further, it was estimated in 2019 that only 4 percent of total funding commitments from the Adaptation Fund was directed to activities specifically targeting ecosystem resilience.[347]

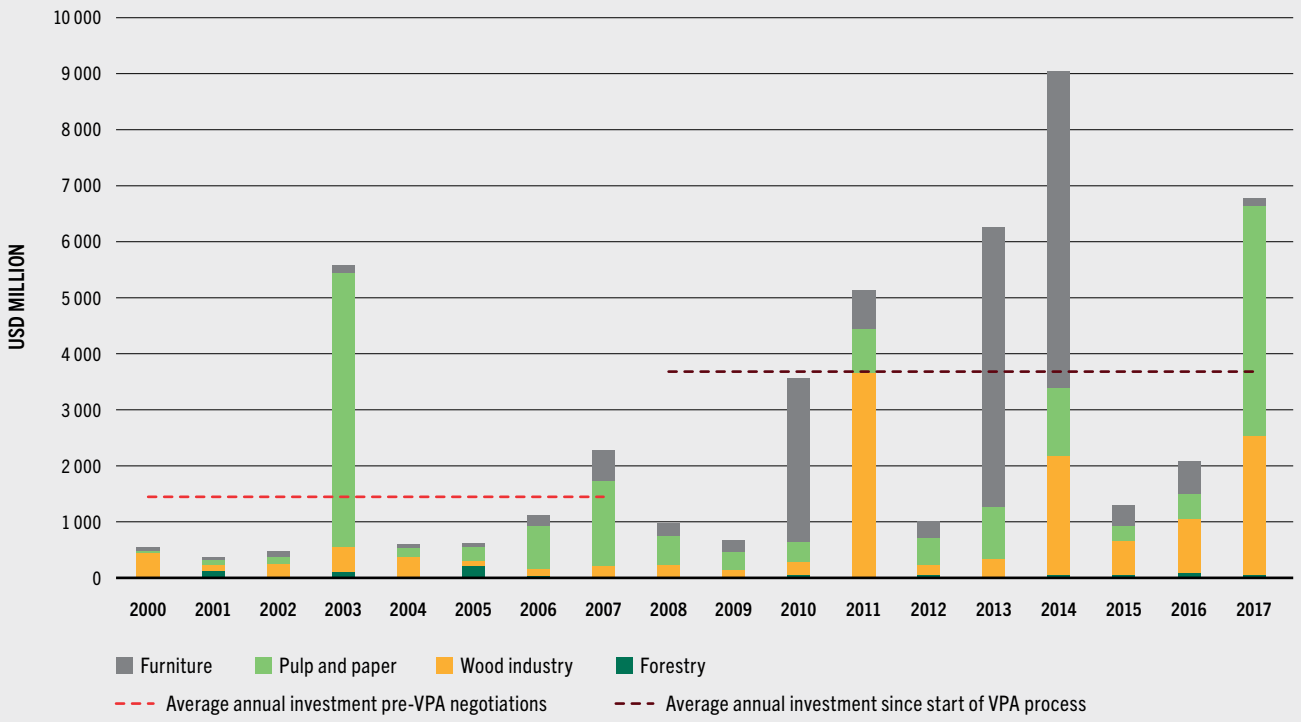
FIGURE 17 GREENNESS OF STIMULUS INDEX, AS OF 30 JUNE 2021, 30 COUNTRIES

NOTE: The methodology to calculate the index is described in Annex 1 (p. 20) of the source document (cited below). The index is constructed by combining the flow of stimulus into five key sectors with an indicator of each sector's environmental impact, the latter accounting for both historical trends and specific measures taken under the country's stimulus. The impact indicator assigns a greenness value (positive or negative) to each sector for every country based on the methodology discussed in Annex 1 of the source document. The overall Greenness of Stimulus Index is an indicator of the total fiscal spending in response to COVID-19 categorized as either a positive or negative impact on the environment. The final index for each country is an average of sectoral impact, normalized to a scale of -1 to +1. The five sectors – agriculture, energy, industry, waste and transport – were chosen for their historical impact on climate and the environment.
SOURCE: Vivid Economics & Finance for Biodiversity Initiative. 2021. *Greenness of Stimulus Index – An assessment of COVID-19 stimulus by G20 countries and other major economies in relation to climate action and biodiversity goals*. (also available at https://a1be08a4-d8fb-4c22-9e4a-2b2f4cb7e41d.filesusr.com/ugd/643e85_f712aba98f0b4786b54c455fc9207575.pdf).

Private finance is traditionally the main source of funding for the sustainable-use pathway but is hard to quantify

The private sector is a hard-to-quantify source of finance for the three forest pathways. The UN Environment Programme (2021) estimated that private finance for nature-based solutions accounted for about 14 percent of total flows for this purpose.[348] The three largest sources of private financing for nature-based solutions (including forests) in 2019 were sustainable supply chains (relevant to the halting-deforestation and sustainable-use pathways); biodiversity offsets, particularly in developed economies (relevant to the halting-deforestation and restoration pathways); and impact investment funds seeking social, environmental and financial returns (potentially relevant to all three pathways).[349] An increasing number of private companies are engaging in forest projects, particularly those on the halting-deforestation and restoration pathways and less so for enhancing sustainable use.[350] Some financial flows, such as investments by small producers in their own land, may be significant but are unreported.[351]

FIGURE 18 ANNUAL INCREASE IN FIXED ASSETS FOR MEDIUM-SIZED AND LARGE ENTERPRISES IN INDONESIAN FOREST SUBSECTORS



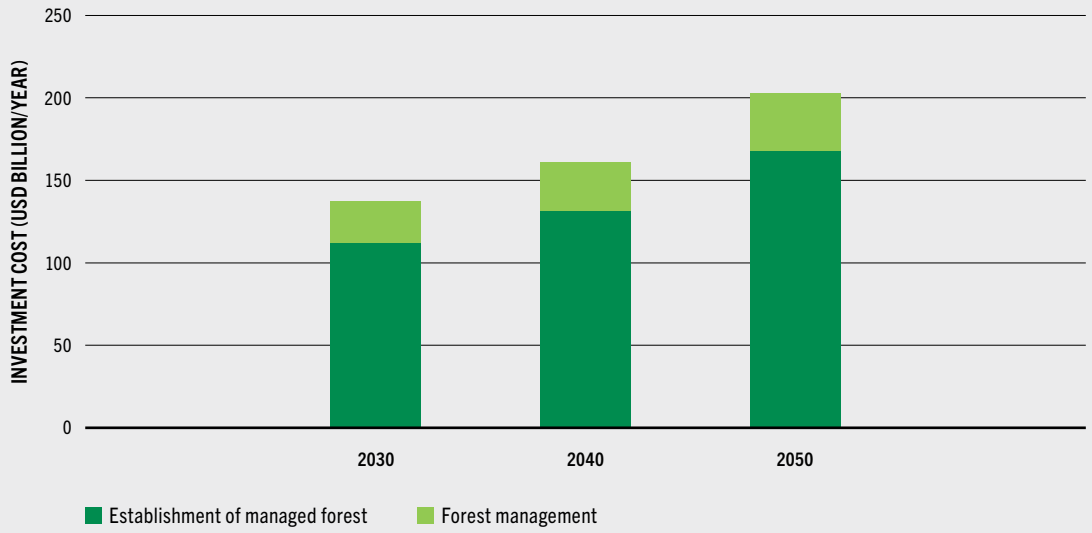
NOTE: VPA = voluntary partnership agreement.
SOURCE: Held, C. 2020. *The impact of FLEGT VPAs on forest sector investment risk in Indonesia and Viet Nam*. Yokohama, Japan, International Tropical Timber Organization.

Existing pledges and commitments by private sector stakeholders mostly involve large consumer-facing organizations and financial institutions; the private forest sector, however, is absent or a minor participant in many existing alliances and initiatives on forest conservation and restoration. The private sector is active in initiatives such as the Forest Investor Club (launched at UNFCCC COP 26), the Forests Solutions Group of the World Business Council for Sustainable Development, the World Economic Forum's Tropical Forest Alliance, the National Alliance of Forest Owners, New Generation Plantations, and Initiative 2020; the private sector presence in many other initiatives is unclear, however.

A challenge in estimating investments for the sustainable-use pathway is the lack of a definition of what constitutes an investment in green value chains.[k] Investments in processing and utilization (e.g. substituting wood for other energy-intensive and non-renewable construction materials) make it possible to "do more with less" – that is, improve efficiency and reduce waste and dependency on non-renewable and carbon-intensive materials. Yet investments in processing facilities can also exacerbate deforestation and degradation if raw materials are sourced unsustainably.

k For example, does an investment in a wood-processing industry qualifies as a green value-chain investment?

FIGURE 19 ADDITIONAL INVESTMENT REQUIRED IN FOREST PATHWAYS UNDER AN "IMMEDIATE ACTION" SCENARIO



SOURCE: United Nations Environment Programme. 2021. *State of finance for nature – Tripling investments in nature-based solutions by 2030*. Nairobi.

Notwithstanding the above caveat, private investment in forest-based value chains is probably higher than reported.[352] According to one (2017) estimate, annual private sector investments in Africa, Asia and Latin America amount to USD 1.5 billion to USD 2 billion in plantations and USD 6.5 billion in wood processing.[353] A more recent analysis found that average annual investment in the last several years has exceeded USD 600 million in Viet Nam and USD 3 billion in Indonesia (investments by small and medium-sized enterprises are included in these estimates if they operated formally).[354] A noticeable feature of Figure 18 (for Indonesia) is that annual investments in wood processing, pulp and paper and furniture are many times those in forestry. In Europe, 25 countries reported total gross fixed capital formation (i.e. investments) of EUR 3.2 billion in 2015, equivalent to about EUR 20 per ha of forest; of this investment, 74.2 percent was spent on equipment and buildings, 16.3 percent on planting trees to provide regular income, and 9.5 percent on other investments in fixed capital, such as roads, fire prevention and tourist infrastructure.[355] For 22 countries for which data were available, gross fixed capital investment increased by 14 percent between 2010 and 2015 (from EUR 2 659 million to EUR 3 035 million).[356]

A recent study on financing for the forest pathways indicated that it needs to increase threefold by 2030 and fourfold by 2050 if the world is to meet its climate, biodiversity and land degradation targets, with the necessary additional finance directed to forest establishment and management alone amounting to USD 203 billion per year by 2050 (Figure 19); if peatland and mangrove restoration and silvopasture (a type of agroforestry) are included, the necessary investment increases to USD 400 billion per year by 2050.[357] ■

4.2 PROMISING DEVELOPMENTS IN MOBILIZING PRIVATE SECTOR FINANCE FOR THE FOREST PATHWAYS SHOULD BE ENCOURAGED AND MONITORED

Even though the private sector is a hard-to-quantify source of finance, its potential to support the scaling up of investments in the forest pathways is significant. There is growing awareness that the loss of ecosystem services provided by forests presents risks that affect the profitability of companies, the financial sector and entire economies, prompting increased attention and investment in the pathways by the private sector.

Private investments in forest conservation and restoration appear to be ramping up

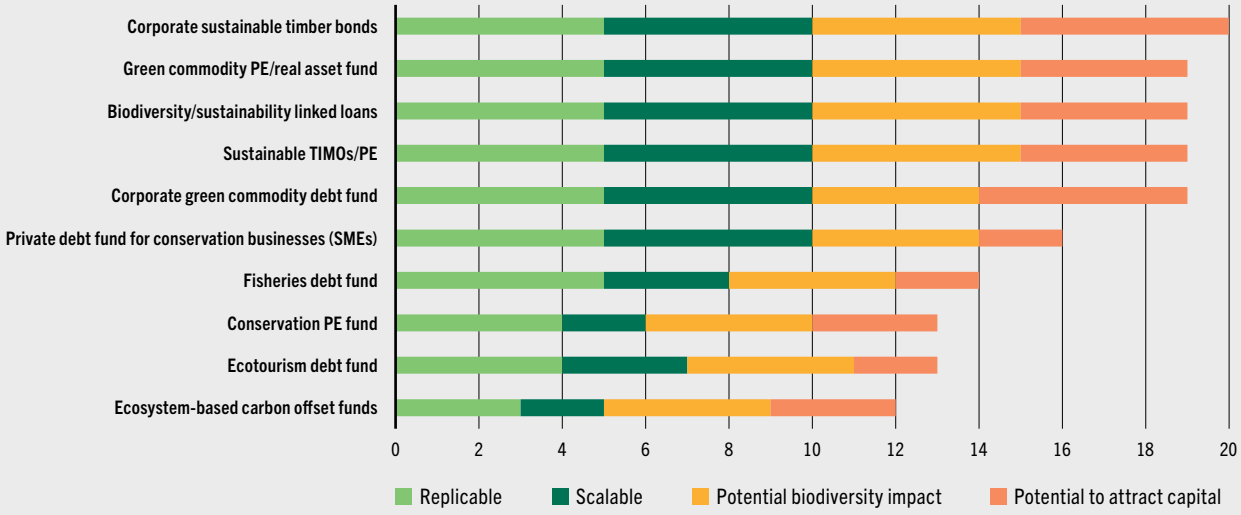
Private companies are increasingly engaging in forest conservation and restoration. According to the World Bank, most of the top ten investment instruments with high feasibility in emerging markets are relevant to forestry (Figure 20).[358] The instrument rated to have the highest potential is corporate sustainable timber bonds, which are bonds issued by timber-based companies (relevant to the halting-deforestation, restoration and sustainable-use pathways), followed by green commodity private equity funds supporting sustainable commodities (halting deforestation and sustainable use); biodiversity/sustainability-linked loans – loans granted based on environmental indicators (halting deforestation, restoration, and sustainable use); timber investment management organizations and private equity (halting deforestation, restoration); corporate green commodity debt funds, which provide loans for sustainable commodities (halting deforestation); private debt funds for conservation businesses, which provide loans to small and medium-sized businesses delivering conservation impacts (halting deforestation); fisheries debt funds – providing loans for sustainable fishing activities (less relevant to forests, although potentially important for mangroves and other coastal forests); conservation private equity funds, which offer private equity to conservation businesses (halting deforestation); ecotourism debt funds, which provide loans for ecotourism businesses (restoration); and ecosystem-based carbon-offset funds, which support carbon-offset strategies through ecosystem conservation/restoration projects (halting deforestation, restoration).

The private sector is developing new business models that integrate multiple sources of finance. For example, Sealaska – a native-owned corporation in Alaska, United States of America – is using an integrated land management approach for its old-growth forest concession in the Tongass National Forest. Traditionally, Sealaska has relied heavily on income from logging but in 2015 it gained access to California's carbon markets, providing a way for the company to diversify its activities. Between 2015 and 2019, the company made USD 100 million selling carbon credits to oil companies.[359] A partnership between a non-governmental organization and a global furniture outlet to create more sustainable wood value chains in Southeast Asia is another example of the financing of transitions to greener value chains (Box 18).

Blended finance models could help de-risk private investments that have significant public value but insufficiently attractive risk–return profiles

The OECD defines blended finance as "the strategic use of development finance for the mobilization of additional finance towards sustainable development in developing countries", with "additional finance" referring primarily to commercial finance.[365] Blended finance refers to financing models pooling together different sources of capital with

FIGURE 20 TOP TEN INVESTMENT INSTRUMENTS WITH HIGH FEASIBILITY IN EMERGING MARKETS, SCORED ACCORDING TO POTENTIAL



NOTE: Potential is rated qualitatively in each category on a scale of 1 (very low) to 5 (very high). PE = private equity; TIMOs = timber investment management organizations; SMEs = small and medium-sized enterprises.
SOURCE: World Bank. 2020. Mobilizing private finance for nature. Washington, DC, World Bank. https://doi.org/10.1596/35984

BOX 18 SUSTAINABLE FORESTRY AND PRODUCTION OF WOOD PRODUCTS – RELEVANT TO THE SUSTAINABLE-USE PATHWAY

In 2006, the World Wide Fund for Nature and IKEA formed a partnership to transform the market landscape for key forest commodities in the Mekong region of Southeast Asia, including acacia plantations in Viet Nam. The partnership aimed to create more sustainable supply chains in which smallholders and forest plantation companies delivered Forest Stewardship Council (FSC)-certified timber for IKEA's global markets.[360] This market link has been instrumental in enabling smallholders to become certified,[361] with the FSC issuing a certificate in 2016 for more than 4 000 hectares of acacia grown by small forest owners. Better business planning and longer harvest cycles produce more valuable timber, and commitment from buyers like IKEA means better prices. This model has increased incomes for plantation households, which sell FSC-certified timber at prices that are 10–18 percent higher than those for non-certified timber.[362] By 2016, the total transaction value between IKEA and its Vietnamese suppliers had reached approximately EUR 100 million (USD 118 million) annually, indicating that opportunities exist to increase market share for those suppliers able to meet certain forestry standards.[363] The improved standards have helped Viet Nam's wood industry, which has set an example for developing tropical countries on how the plantation forestry and wood-product sectors can increase rural development, rural livelihoods and national income.[364]

BOX 19 EXAMPLES OF BLENDED-FINANCE EFFORTS TO RAISE MONEY FOR SUSTAINABLE FORESTRY

New Forests' Tropical Asia Forest Fund 2. A group of institutional investors, development finance institutions, endowments and corporate investors are attempting to raise USD 300 million with a view to investing in sustainable, Forest Stewardship Council-certified plantation forestry in Southeast Asia (Cambodia, Indonesia, the Lao People's Democratic Republic, Malaysia and Viet Nam) to meet rising timber demand in domestic and export markets. Blended finance would comprise 10–15 percent of impact/"concessional" equity for funding activities such as environmental habitat restoration, peatland rewetting and community outgrower schemes in the fund's plantation companies. Investors in the fund are also interested in long-term carbon credit offtake from fund activities.[366]

The Green Climate Fund's new Amazon Bioeconomy Fund. The USD 600 million programme will include an investment of USD 279 million from the Green Climate Fund, and it will be implemented with the Inter-American Development Bank. It will encourage private investment in six key areas of the bioeconomy: (1) sustainable agroforestry; (2) native palm cultivation; (3) non-timber natural forest products; (4) growing native-species timber; (5) aquaculture; and (6) community-led nature tourism.[367]

Komaza Smallholder Forestry Vehicle. The aim of Komaza, a smallholder company in Kenya, is to address increasing wood demand in Africa and include small farmers in commercially viable operations. Komaza was built up initially with grant money from social enterprises, enabling it to obtain development and commercial money through convertible loans and equity investments from various entities. Financiers also invested in Komaza, helping it build assets in trees and a range of small to medium-sized processing facilities. After 14 years, the company now has thousands of partners, a value of more than USD 20 million and expertise across the whole value chain. In 2020, Komaza reached an equity finance agreement worth USD 28 million with the Dutch Development Bank. Farmers provide land and labour and the company provides technical assistance and the required inputs for tree-farming. This helps keep costs down (in conventional plantations, labour may comprise more than half the total cost), while farmers can invest in their plantations without getting into debt and convert their labour into assets (trees). When trees have reached an appropriate size, the company harvests, transports and sells them, sharing sales revenues with the farmers. Subsistence farmers sometimes find it difficult to obtain documentation to support their claims of ownership of land and other assets, which they need to obtain commercial loans. To become a partner of Komaza, however, a farmer's ownership can be recognized by neighbours, chiefs and community leaders. To date, nearly 6 000 farmers have planted 2 million trees in about 4 000 ha under the scheme.[368]

different returns and maturity expectations. Such models can enable the mobilization of public, private and international sources of financing by investment funds. They are increasingly being explored by international public funding mechanisms such as the Global Environment Facility in support of global environmental goals. In such approaches, public finance helps unlock private capital, thus increasing the finance available for investments that traditional investors consider too risky. Box 19 presents three recent examples of blended-finance approaches with the potential to support the three pathways.

Several forest companies are engaged in structuring blended-finance vehicles to invest in sustainable forest management, with conservation and restoration co-benefits.

Green bonds are emerging, but only 3 percent are oriented towards nature-based solutions

Green bonds are debt securities issued on the financial markets with the specificity of financing (or refinancing) projects with environmental benefits; they are an important part of the sustainable finance market, which has grown

exponentially in recent years. In particular, the green bonds market has undergone continuous growth since 2014. This market is dominated by the energy, transport and building sectors – as of 2019, the land-use sector, which includes forestry, had attracted only 3 percent of green bonds (Figure 21).[369] Nevertheless, forestry companies have also issued green bonds (Box 20).

Most issuers of green bonds are countries with developed economies; among developing economies, Chile, China and Indonesia are significant issuers. The Conservation Fund (based in the United States of America) launched a USD 150 million green bond in 2019, which was the first pure conservation green bond of its kind. The European Commission recently adopted a green bond framework, thus moving towards the issuance of up to EUR 250 billion in green bonds; the framework provides investors in these bonds with confidence that the mobilized funds will be allocated to green projects and that the Commission will report on their environmental impacts.[370]

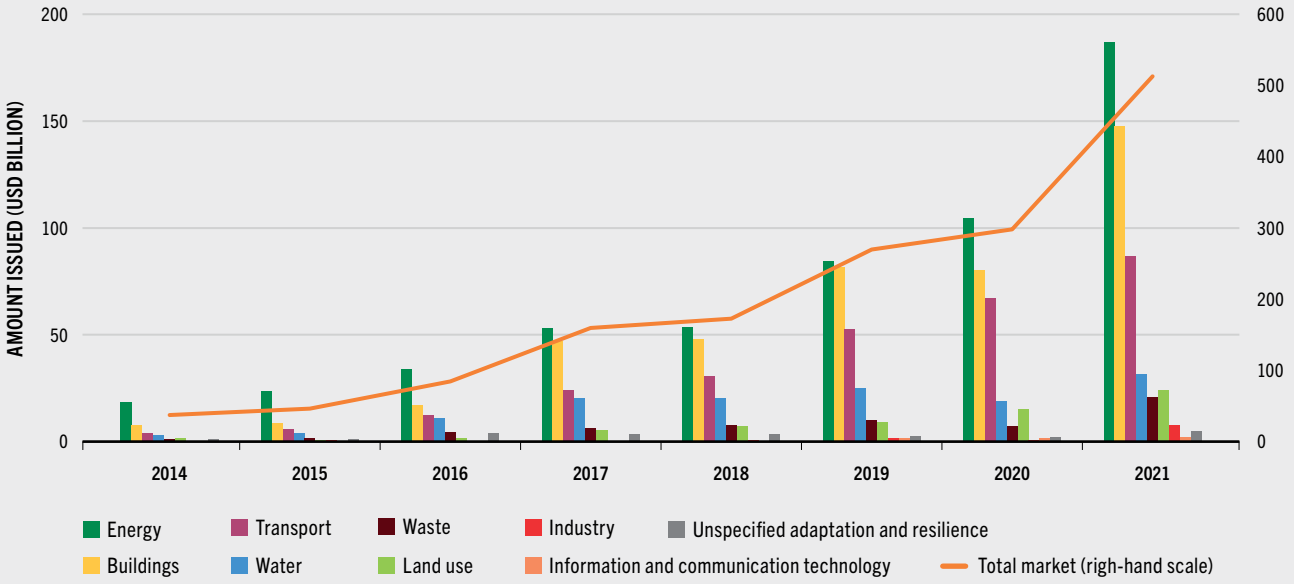
Private finance pledges send good signals, but more support to public and private institutions is needed to develop pipelines of investment-grade projects

Numerous meetings and fora have highlighted that the "where from" of finance (i.e. where to find additional finance for forestry) is easier to answer than the "where to" (i.e. where to invest in emerging and developing economies so as to generate economic, social and environmental returns).[371] In many developing and emerging countries, the where-to question is constraining forest-based progress – the availability of large quantities of finance needs to be met with large opportunities to invest. To attract significant finance to restoration and sustainable use, countries need scalable, credible pipelines of good investment-grade projects. One means for developing such pipelines would be to set up investment facilities or hubs to help small and medium-sized enterprises, communities, smallholders and their organizations that operate in forest value chains to aggregate their production, add value and prepare quality projects; tools to help inform investment decisions could also be developed and deployed.

Several initiatives have been developed in recent years to help create pipelines of bankable projects. The Land Accelerator is supporting entrepreneurs and small and medium-sized enterprises to develop and scale up business models that combat deforestation and restore forests. To date, 191 entrepreneurs from 46 countries have benefited from the programme. The Restoration Factory, launched in 2021, provides mentoring to entrepreneurs engaging in ecosystem restoration. Various models exist for project preparation and technical assistance facilities. Some are open to a wide range of funds and investors: the Nature+ Accelerator Fund, which started operation in 2021, supports project development at various maturity steps. Other project preparation facilities and technical assistance facilities are directly attached to funds, such as those associated with the Land Degradation Neutrality Fund, the &Green Fund and the Agri3Fund.

New investment vehicles supporting the forest pathways have been accelerated through programmes such as the International Climate Finance Accelerator. The aim of the Restoration Seed Capital Facility, launched in 2021, is to speed up the design of investment vehicles contributing to FLR, including through targeted support for the development of a pipeline of bankable projects. Lessons learned from these programmes can be capitalized on and further efforts and resources allocated by governments and investors to continue developing investment-grade projects. ■

FIGURE 21 THE GREEN BONDS MARKET, 2014–2021



SOURCE: Climate Bonds Initiative, personal communication, February 2022.

BOX 20 GREEN BONDS – FUNDING FOREST PATHWAYS

Klabin is a Brazilian producer and exporter of packaging paper with industrial units in Brazil and Argentina. All of Klabin's forest stewardship units are independently certified, including 229 000 ha of forest plantations and 215 000 ha of native forests set aside for conservation. Klabin adopted the mosaic restoration concept for its sustainable forest management: plantations are interspersed with areas of native forests. The company has developed green bonds, which represent financing opportunities for the three pathways. The company issued two green bonds (USD 500 million due in 2027) and a sustainability-linked bond (USD 500 million due in 2031). Between 2015 and 2020, approximately USD 345 million was spent on eight eligibility criteria, including USD 216 million in sustainable forest management and USD 12 million in native forest restoration and biodiversity conservation.

SOURCE: FAO Advisory Committee on Sustainable Forest-based Industries. 2021. Background paper on status, challenges, and opportunities of forest-based industries engagement for ecosystem restoration (business rationale and financing solutions as drivers for restoration). FAO. Unpublished.

4.3 ALIGNING INCENTIVES, REGULATIONS AND MARKETS WITH SUSTAINABILITY CAN CATALYSE A TRANSFORMATION TOWARDS INCLUSIVE AND SUSTAINABLE GREEN ECONOMIES

Sections 4.1 and 4.2 concluded that domestic public finance is the most significant source of finance for forests and that private investments, although hard to quantify, have potential for scaling up the pathways.

Increasing investment also depends on the strategic use of various policy instruments to reorient fiscal and non-fiscal incentives and boost green markets and financing through enhancers such as carbon markets, sustainable finance and related regulatory instruments, sustainable value chains and sustainability certification.[l] Governments can incentivize the three forest pathways by:

- repurposing agricultural subsidies to reward the sustainable management of forests and farmlands;
- introducing environmental taxation that encourages forest conservation and generates income;
- promoting fiscal incentives that offer tax deductions for companies that meet the required sustainability standards;
- allocating ecological fiscal transfers to subnational governments that demonstrate improved management of forest assets; and
- putting in place standards, regulations and due-diligence requirements and improving data and financial regulation and supervision to ensure that the private sector manages risks adequately.

Each of these is discussed further below.

Repurposing agricultural subsidies – currently almost USD 540 billion per year – to include agroforestry and forestry could help avoid the harmful impacts embodied in 86 percent of such subsidies

Agricultural support policies can be redesigned to avoid incentives for land expansion and instead encourage sustainable intensification,[372,373] agroecological systems, agroforestry,[374] and the sustainability of forest-based value chains.[375,376] In 2021, FAO, the UN Development Programme and the UN Environment Programme estimated the value of support for agricultural producers globally at almost USD 540 billion per year and noted that this support is heavily biased towards measures that are distorting (thus leading to inefficiency), unequally distributed, and harmful for the environment and human health.[377] Price incentives (e.g. border measures that affect trade and domestic market prices) and fiscal subsidies tied to the production of specific commodities (which can promote the overuse of inputs and overproduction) are considered the most distorting and environmentally and socially harmful forms of producer support and are estimated to account for about 86 percent of total support.[378] Thus, producers are disincentivized to behave in a manner that is efficient, sustainable and climate-friendly, and there is insufficient backing for public goods such as agricultural research and advisory and extension services.

l According to the Global Green Finance Index, policy and regulatory frameworks are the number-one driver of green finance (i.e. the factor that most affects the uptake of green finance). See Chart 44 and Table 23 in: Mills, S., Wardle, M. & Mainelli, M. 2021. *The Global Green Finance Index 7.* Z/Yen. (also available at https://www.longfinance.net/media/documents/GGFI_7_Report_2021.04.29_v1.1.pdf).

Environmental taxation, fiscal incentives and ecological fiscal transfers can encourage investment in the forest pathways

Domestic fiscal policies for land-use sectors can provide contradictory incentives or promote deforestation and other socially and environmentally harmful effects.[379,380,381] Under French tax law, for example, the presence of trees on farmland decreased the surface area eligible for subsidies until a reform in 2010.[382]

Variable tax rates are increasingly available as a policy instrument to forest fiscal administrators. For example, there has been substantial development in monitoring, reporting and verification (MRV) systems since the creation of REDD+ and, in some countries, these are now sufficiently developed to implement environmentally responsive fiscal policies such as ecological fiscal transfers (EFTs; see below). The recent growth of other instruments – particularly third-party sustainability certification schemes such as those of the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC) – enables policy combinations that may also work for governments with relatively low MRV capacity. For example, Brazil and Peru levy lower concession fees and rebates for certified operations. In Gabon, a lower area tax is imposed on certified concessions.[383]

EFTs are additional allocations of tax revenues to subnational governments that demonstrate improved ecosystem management; in 2020, they amounted to USD 23 billion globally, which is about 20 times the ODA for forestry.[410] Brazil, China, France, Portugal and, most recently, India make use of this mechanism. In India, states receive a portion of central revenues based on the percentage of forest cover; about USD 37 billion was transferred as EFTs to states on this basis in the period 2016–2020.[384] Other indicators can be used, such as the quality of ecological services provided, reductions in forest fire, avoided or reduced deforestation, and areas certified under forest management plans or those with third-party sustainability certification. For some indicators, the necessary data might already be available; for others, the use of EFTs would first require investment in adequate MRV systems.

Countries are adopting standards, regulations and due-diligence requirements to divert financial flows away from projects and investments that are harmful to forests

The growing deployment of environmental standards (and related certification and labelling) means that buyers, consumers and users increasingly have access to information on the environmental credentials of the processes involved in producing the forest goods and services they purchase. By influencing market access and participation in value chains, certification and due-diligence requirements and systems can reassure consumers and investors alike that environmental and social standards have been adhered to. Certification, standards and due-diligence requirements are shaping not only market access[385,386] and trade (Box 21) but also investments in agrifood commodities.

Karsenty (2021) outlined a range of potential uses for standards and regulations, including the following:[409]

- Governments could include sustainability criteria in tendering processes for forest harvesting contracts. In Sarawak, the Malaysian Timber Certification Scheme (the national system, endorsed by the PEFC) will become compulsory by 2022. In Gabon, all concessions should be certified by the FSC by 2022 (although this deadline may be postponed to 2025). The Congo's new forest law mentions compulsory certification for forest concessions.
- Public timber procurement policies could favour certified legal or certified sustainable timber.
- Environmental compensation mechanisms could be put in place, such as in Brazil, where a percentage of private land – called "legal reserves" – must be kept under natural vegetation (in the case of forests, such areas may be used for sustainable timber production). Compliance with this legal provision is essential for owners wishing to register in the rural environmental

BOX 21 BUILDING VERIFICATION SYSTEMS FOR LEGAL AND SUSTAINABLE WOOD PRODUCTS – EXPERIENCES IN FOREST LAW ENFORCEMENT, GOVERNANCE AND TRADE

Asserting that wood comes from legal and sustainable sources requires an adequate verification system. Over the last decade, demand-side action has focused on trade regulations that require importers to apply due diligence to ensure the legality of their sources. Significant efforts have been made to build cost-effective systems that can provide assurance in wood value chains, and this trend is extending into other agricultural commodities such as cocoa, coffee and palm oil. Private sector associations and producer organizations have developed systems to facilitate raw-material sourcing and to demonstrate the legality and sustainability of products. Efforts have included clarifying legal frameworks, increasing transparency and independent monitoring and strengthening the participation of civil society and the private sector in governance processes.

For example, the European Union, the United States of America and other timber-importing countries have put regulations in place to limit trade in illegally sourced timber and forest products, in part to reduce deforestation and degradation caused by unsustainable forest use. Fifteen tropical countries are negotiating or implementing voluntary partnership agreements (VPAs) with the European Union, the aim of which is to ensure that all exports of timber products comply with national laws and regulations. The VPA partner countries account for 25 percent of the world's tropical forest cover and 80 percent of the European Union's tropical timber imports. VPA processes have improved transparency, participation, legal clarity, accountability and other aspects of good forest governance.[387]

The introduction and implementation of such systems can inadvertently discriminate against smaller and community-based producers, processors and traders by increasing the cost of production or simply by excluding rather than including them in formal supply chains. Analysis, open dialogue with such stakeholders and adequate safeguards are needed to minimize the risk of adverse impacts.

cadastre, which allows access to various financial benefits and authorizations. If a property does not meet these environmental requirements, however, owners may compensate for this missing area by acquiring environmental reserve quotas from another rural property.

There are many opportunities for applying standards, regulations and due-diligence processes to encourage sustainable forestry. One of the obstacles to their implementation, especially in tropical countries, is a lack of human resources in companies.[388] The adoption of incentives must therefore be accompanied by efforts to strengthen the capacity of potential change agents.

A different set of rules concerns financial requirements that influence financial flows. First steps in this direction would include clarifying sustainable forestry as an "investable asset"; bringing considerations relevant to the forest pathways to dialogues on disclosures/taxonomies; and embedding recommendations from the Taskforce on Nature-related Financial Disclosures and the Task Force on Climate-related Financial Disclosures in the practices of companies and investors. Similarly, the development of sustainable finance frameworks such as the European Union Sustainable Finance Taxonomy present opportunities for channelling more investment towards nature-based projects, including the forest pathways. The Coalition of Finance Ministers for Climate Action comprises fiscal and economic policymakers from over 60 countries with the intention of shaping the global climate response and securing a just transition towards low-carbon, resilient development. All these initiatives, which bring together high-level decision-makers from the public and private sectors, have transformational potential if forest pathways and goals are properly considered.

BOX 22 EXAMPLES OF INITIATIVES ON ISSUES RELATED TO AGRICULTURAL COMMODITIES AND FORESTS

- The Forest, Agriculture and Commodity Trade Dialogues initiative launched by the Presidency of the 26th Conference of the Parties to the UN Framework Convention on Climate Change and the Tropical Forest Alliance to accelerate the transition towards more sustainable land-use practices.
- The Forest Positive Coalition launched by the Consumer Goods Forum to accelerate systemic efforts to remove deforestation, forest degradation and conversion from key commodity supply chains (palm oil, soy, paper, pulp and fibre).
- The Sustainable Cocoa Initiative, involving the European Union, Cameroon, Côte d'Ivoire and Ghana.
- The comprehensive economic agreement signed between Indonesia and the member states of the European Free Trade Association (Iceland, Liechtenstein, Norway and Switzerland).[391] Under the agreement, which entered into force in November 2021, Swiss tariffs on palm-oil imports will be reduced by 20–40 percent if the palm oil complies with certain sustainability goals.[392]
- The Joint Working Group on Palm Oil between the European Union and certain Association of South East Asian Nations member countries.
- Action Track 3 of the Food Systems Summit, "Boost Nature-positive Food Production", and the coalition on "Halting Deforestation and Conversion from Agricultural Commodities".
- The Global Environment Facility 7 Impact Program, "Forest Systems, Land Use and Restoration".

Regulatory measures governing traded goods are being put in place to decouple agriculture and deforestation – complementary support for producer countries is needed

A significant and growing share of the commodities produced on new agricultural land feeds international trade.[389,390] Regulatory frameworks are being developed in some markets to avoid the placement of products associated with deforestation or forest degradation. Awareness is also growing among countries about the need to address environmental damage while simultaneously increasing food security for all. Some governments, companies and others have committed to addressing this – such as in a 2010 resolution on deforestation by the Consumer Goods Forum, the Amsterdam Declarations partnership and the 2014 New York Declaration on Forests. Box 22 provides other examples of initiatives to address issues related to agricultural commodities and forests.

Sources of finance are increasingly requiring more transparency on deforestation in value chains

Sources of finance are increasingly seeking to clarify, eliminate, reduce and mitigate their adverse environmental, social and governance impacts (Box 23). In general, this has moved from being viewed as an expensive approach that is bad for business to a business strategy that is good for long-term growth and risk management.[393]

The Central Banks and Financial Supervisors Network for Greening the Financial System is investigating the linkages between biodiversity loss, macro-economics and finance.[394] The Taskforce on Nature-related Financial Disclosures was established in 2021 with the objective of developing a framework for organizations to report and act on evolving nature-related risks in order to support a shift in global financial flows away from nature-negative outcomes and towards nature-positive outcomes.[395] ■

BOX 23 INTEGRATING ENVIRONMENTAL CRITERIA INTO FINANCIAL DECISIONS

To fulfil their role in managing and distributing risks and allocating resources to productive uses, central banks, financial-sector regulators and supervisors are increasingly seeking to integrate environmental criteria into financial decisions, including through environmental risk assessments, increased transparency and the adoption of standards and impact reporting. Action in the following four areas would be transformative:

1. **Taxonomies and labelling.** Develop taxonomies for identifying economic activities that contribute to sustainable use and the provision of ecosystem services (such as the European Union's Sustainable Finance Taxonomy and Mongolia's Green Taxonomy, which explicitly includes forestry); and promote the standardization and broad use of environmental metrics for impact reporting across sustainable financing mechanisms.
2. **Supervisory and regulatory risk assessment.** Develop tools and methodologies to integrate nature-related risks into the financial stability monitoring and supervisory approaches of central banks and supervisors and encourage or require the inclusion of environmental criteria in risk assessments and investment processes in the financial sector.
3. **Disclosure.** Promote the disclosure of nature-related information by leveraging the experiences and initiatives of other countries, such as through the Taskforce on Nature-related Financial Disclosures.
4. **International networks.** Support networks such as the Network for Greening the Financial System, the Coalition of Finance Ministers for Climate Action and the Sustainable Banking Network to facilitate the standardization of nature and biodiversity risk assessment in supervisory tools and approaches, and help regulators adopt them.

SOURCES: World Bank. 2020. *Mobilizing private finance for nature*. Washington, DC, World Bank. https://doi.org/10.1596/35984
World Bank. 2021. *Designing fiscal instruments for sustainable forests*. Washington, DC. (also available at https://www.climateinvestmentfunds.org/sites/cif_enc/files/knowledge-documents/designing_fiscal_instruments.pdf).

4.4 THE POTENTIAL OF CLIMATE FINANCE TO ASSIST DEVELOPMENT OF THE FOREST PATHWAYS IS SIGNIFICANT, WITH CARBON MARKETS EXPERIENCING SIGNIFICANT GROWTH

Climate finance has a complex architecture to direct financial flows towards climate-change mitigation and adaptation activities, including through results-oriented mechanisms such as carbon markets and REDD+. The UNFCCC COP 26 has further elevated the importance of climate in the global agenda. There, countries and the private sector made financing pledges of nearly USD 20 billion and have agreed on new rules governing carbon markets, which are expected to grow significantly and have considerable potential to support the pathways (Box 24).

The sale of carbon offsets improves the financial attractiveness of the three forest pathways. Carbon markets are expected to continue growing

Many forestry projects improve their financial attractiveness and justify larger investments by selling carbon offsets. These can be earned in various forest-related projects, such as tree-planting, improved forest management with reduced-impact logging, and avoided deforestation. Carbon credits are issued into registries after third-party verification to assess additionality, baseline setting, emissions monitoring, leakage and permanence. The impact on the ground of such projects

BOX 24 THE CRUCIAL ROLE OF FORESTS ACKNOWLEDGED AT THE 2021 UN CONFERENCE ON CLIMATE CHANGE

The Glasgow Climate Pact is an outcome of negotiations at the 26th Conference of the Parties (COP 26) to the UN Framework Convention on Climate Change, held in Glasgow, Scotland, in late 2021. The pact calls for a doubling of adaptation finance by 2025 and for developed Parties to meet a commitment of USD 100 billion annually by 2025.

In the context of negotiations on Article 6 of the Paris Agreement (carbon markets), countries agreed to set rules to strengthen the integrity of carbon markets (covered under Article 6.2, Article 6.4 and Article 6.8) and create a new global carbon-offsetting mechanism (including forestry). Progress was made on several aspects at COP 26, including that 5 percent of the proceeds from collected offsets will be redirected towards the Adaptation Fund for developing countries.

In the Glasgow Leaders' Declaration on Forests and Land Use, also announced at COP 26, the leaders of more than 140 countries, accounting for more than 90 percent of the world's forests, committed to work together to halt and reverse forest loss and land degradation by 2030. The pledge was backed by USD 12 billion in public funding (the "Global Forest Finance Pledge") and USD 7.2 billion in private funding. More than 30 financial institutions (with more than USD 8.7 trillion in global assets) committed to eliminating investments in activities linked to agricultural-commodity-driven deforestation.

SOURCE: Anonymous. 2021. Glasgow Leaders' Declaration on Forests and Land Use. In: U*N Climate Change Conference UK 2021* [online]. [Cited 2 February 2022]. https://ukcop26.org/glasgow-leaders-declaration-on-forests-and-land-use/

varies hugely, depending on the type of project. Carbon credits constitute a funding source for projects that could not be implemented otherwise and therefore have the potential to generate manifold benefits. Various funds are being set up to take advantage of this financing opportunity (Box 25).

Demand for carbon credits originates in a range of carbon markets, broadly grouped as voluntary markets (often related to the voluntary offsetting targets of firms) and compliance markets (based on regulations that oblige firms to reduce emissions).

The global voluntary offset markets generated nearly USD 400 million in 2017–2019 through 105 million ($MtCO_2e$) forestry carbon credits.[398] This market continues to expand, with transactions (as of August 2021) exceeding USD 0.5 billion (Table 6). Compliance markets, although still small, far exceed the value of voluntary markets: for example, the California–Quebec emissions trading system (ETS) issued 83 million forestry carbon credits valued at USD 1.2 billion in 2017–2019, and the New Zealand ETS issued 38 million forestry carbon credits with a value close to USD 800 million.[399] Other compliance markets generating significant demand for forestry carbon credits include Australia's Emissions Reduction Fund, Colombia's carbon tax and the Republic of Korea's ETS. Demand in carbon markets is modest at a global scale (although it could be significant nationally and subnationally, such as in Colombia, New Zealand and California). Much of the attention on carbon markets is in expectation of future growth – although this is uncertain. Even if forest offset markets grow in volume and pricing, the extent to which they would offer opportunities for investment in the forest pathways is unclear.

The recent agreement at UNFCCC COP 26 on detailed rules for carbon-credit transfers between countries supports expectations of future carbon market growth. Using the Paris Agreement's Article 6, governments can now use carbon credits (referred to as internationally transferred mitigation outcomes, or ITMOs, in Article 6) to meet their mitigation commitments. A process for both the public and private sectors to generate ITMOs will be developed in coming years, which is expected to also cover nature-based solutions. Countries can use the newly available framework to offset part of their mitigation commitments, which could create significant additional demand for carbon credits. There was much contention in the UNFCCC

BOX 25 FUNDS FOR SEQUESTERING CARBON THROUGH FORESTRY

The aim of the Restore Fund is to invest in forestry projects that will remove carbon from the atmosphere while generating financial returns for investors. Launched in early 2021 by Apple, with Conservation International and Goldman Sachs, the USD 200 million fund aims to sequester at least 1 million tonnes of carbon dioxide equivalent annually. In 2020, the International Civil Aviation Organization included forestry among eligible options for airline offsetting.[396] In 2021, a public–private consortium launched a call for proposals to purchase up to USD 1 billion in carbon credits for forestry activities.[397]

TABLE 6 VOLUNTARY CARBON MARKET SIZE BY PROJECT CATEGORY, 2019–31 AUGUST 2021

	2019			2020				2021 (through August)			
	Volume ($MtCO_2e$)	Price per tonne (USD)	Value (USD million)	Volume ($MtCO_2e$)	Volume % change from previous year	Price per tonne (USD)	Value (USD million)	Volume ($MtCO_2e$)	Volume % change from previous year	Price per tonne (USD)	Value (USD million)
Forestry and land use	36.7	4.33	159.1	48.1	30.9	5.60	269.4	115.0	139.4	4.73	544.0
Renewable energy	42.4	1.42	60.1	80.3	89.4	0.87	70.1	80.0	0.3	1.10	88.4
Energy efficiency/fuel switching	3.1	3.87	11.9	31.4	921.0	1.03	32.3	16.1	48.9	1.57	24.2
Agriculture	–	–	–	0.3	–	9.23	2.8	3.4	876.8	1.36	4.6
Waste disposal	7.3	2.45	18.0	8.3	13.0	2.76	22.9	2.7	67.5	3.93	10.6
Transportation	0.4	1.70	0.7	1.1	165.2	0.64	0.7	2.1	99.3	1.00	2.1
Household devices	6.4	3.84	24.8	3.5	45.4	4.95	17.3	1.8	49.8	5.75	10.4
Chemical processes/ industrial manufacturing	4.1	1.90	7.7	1.3	68.7	1.90	2.5	1.1	11.2	3.22	3.5

SOURCE: Donofrio, S., Maguire, P., Myers, K., Daley, C. & Lin, K. 2021. *State of the Voluntary Carbon Markets 2021*. (also available at www.forest-trends.org/publications/state-of-the-voluntary-carbon-markets-2021/).

negotiations on the merits of offsetting, however, and restrictions were introduced on ITMO exports (through a need for "corresponding adjustments" – that is, to deduct exported volumes from own performance against targets). More clarity is needed on the interest of countries in using Article 6 before the scale of additional demand and supply can be gauged.

A key step for obtaining access to carbon markets for projects and programmes is working towards compliance with the requirements

of a given carbon standard and registering in its transaction registry. Large forestry firms – whether in plantations or natural forests – find accessing carbon markets challenging; small and medium-sized enterprises and small farmers require specialized help to gain access to such markets, which might come from project developers able to aggregate hundreds and even thousands of smallholders to constitute a sizeable project area.

Result-based payments for REDD+ are evolving to ensure they deliver climate-change mitigation results with environmental integrity and adequate benefit-sharing

REDD+ was originally conceived and structured around the novel concept of RBPs: that is, payments made on the achievement and independent verification of a pre-agreed set of carbon emissions reduction results over a given time frame, as per UNFCCC guidelines, or the achievement of a predefined set of results related to, for example, progress made in the readiness or implementation of policies and measures for addressing drivers of deforestation and forest degradation. Mozambique recently received USD 6.8 million from the Forest Carbon Partnership Facility for reducing 1.28 million tonnes of carbon emissions since 2019.

Of all disbursements estimated by the largest results-based climate finance funds,[m] the forest and land-use sectors have been by far the main recipient.[400] RBPs continue to evolve as climate finance funds and their donors assess the efficacy and efficiency of this instrument. Attention is now being directed towards the delivery of results with sufficient environmental integrity (e.g. with proper accounting frameworks) and benefit-sharing mechanisms (Box 26). The forest finance portfolios in the Green Climate Fund and the Global Environment Facility continue to evolve. For example, the Green Climate Fund project portfolio on forests and land use currently (December 2021) stands at 52 projects and USD 1.5 billion.[401]

Markets for carbon-neutral and sustainable products require credible monitoring, reporting and verification systems – and these are improving

Systems for monitoring, reporting and verifying the efficacy of investments and interventions to reduce deforestation and degradation and to produce carbon-neutral and sustainably produced products must be sufficiently robust to assure donors and companies that results have sufficient environmental integrity. Nesha *et al.* (2021)[402] assessed the use and quality of forest data for national reporting to the FRA in 236 countries and territories. They found that, globally, the number of countries monitoring forest area at good to very good capacities increased from 55 in FRA 2005 to 99 in FRA 2020 when using remote sensing and from 48 to 102 when using national forest inventories.[403] Overall, MRV capacity improvements are most widespread in the tropics, which can be linked to international investments for forest monitoring associated with REDD+.[404] Chagas *et al.* (2020) assessed several carbon standards, focusing on additionality, baseline setting, the quantification of emission reductions (particularly uncertainty), permanence and leakage; they concluded that forest carbon credits may be considered a reasonable option for corporate offsetting provided stringent rules are in place to provide sufficient assurance that such credits come with the environmental integrity equivalent to those generated in other sectors.[405] ■

m Results-based climate finance funds include the Green Climate Fund, the Forest Carbon Partnership Facility, the Bio Carbon Fund Initiative for Sustainable Forest Landscapes, the Carbon Initiative for Development, the Pilot Auction Facility, the Transformative Carbon Asset Facility, the Carbon Partnership Facility (specifically the funds in this facility dedicated to piloting new carbon market mechanisms), REDD Early Movers, Norway's International Climate and Forest Initiative, Energising Development, the Global Energy Transfer Feed-in Tariffs Program, the German Government's N2O Initiative and the Nordic Climate Facility.

BOX 26 RESULTS-BASED PAYMENTS IN THE GREEN CLIMATE FUND

The Green Climate Fund (GCF) has made results-based payments (RBPs) to countries that reported emission reductions to the UN Framework Convention on Climate Change. As of November 2020, the GCF had approved a total financial volume of USD 497 million in eight countries that had demonstrated results and met the requirements for receiving RBPs under the GCF REDD+ pilot programme. An analysis of options for the programme's next phase identified two key themes: equity in access; and ensuring sufficient environmental integrity. RBPs can help strengthen policy coherence if disbursements to recipient countries are made on the achievement of pre-agreed policy milestones and the proceeds are reinvested in activities in line with the country's nationally determined contributions, its REDD+ strategies, and its low-carbon development plans.

4.5 GETTING FINANCE TO SMALL-SCALE PRODUCERS WILL BE ESSENTIAL FOR IMPLEMENTING THE PATHWAYS — LESSONS FROM SUCCESSFUL AND SCALABLE EXPERIENCES NEED TO BE SHARED

Despite being key stakeholders in many forest value chains, smallholders are often perceived to carry additional costs and risks for investment projects, for example because of a lack of collateral. High transaction costs due to value-chain fragmentation, the informal nature of trade interactions, and scalability issues are additional barriers to investments in smallholder-driven projects.[406,407]

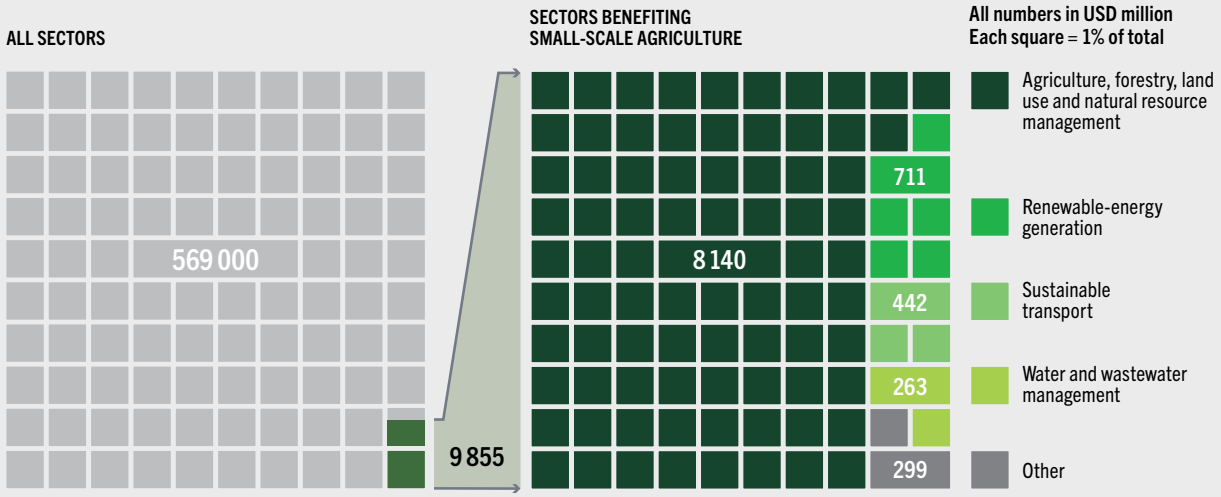
Small producers received less than 1.7 percent of climate finance in 2019, and the situation does not appear to have improved since

Small farms (i.e. less than 2 ha) account for 84 percent of all farms worldwide; they operate on about 12 percent of all agricultural land but produce roughly 35 percent of the world's food.[408] Small farms receive a very small amount of climate finance (Figure 22) – less than 1.7 percent of such flows in 2019.[409] Donor support to Indigenous Peoples and local communities for forest management was reported at USD 250 million to USD 280 million per year between 2018 and 2020.[410] This amount could increase significantly following the UNFCCC COP 26 pledge to allocate USD 1.7 billion between 2021 and 2025 (representing roughly twice as much funding from bilateral sources and foundations as in the previous period) to advance the forest tenure rights of Indigenous Peoples and local communities and support their role as guardians of forests and nature.[411]

New approaches are helping mobilize investment for smallholders, including to reduce perceived risks for investors

Strategies to de-risk smallholder projects, such as using trees as collateral for loans (Box 27) and building assets based on income from ecosystem services (Box 28), can mobilize more investment in small-scale stakeholders.

FIGURE 22 PROPORTION OF CLIMATE FINANCE BENEFITING SMALL-SCALE AGRICULTURE



NOTE: Amounts are per year for 2017/2018.
SOURCE: Chiriac, D. & Naran, B. 2020. *Examining the climate finance gap for small-scale agriculture*. Climate Policy Initiative. (also available at https://www.climatepolicyinitiative.org/publication/climate-finance-small-scale-agriculture).

Production risks to smallholders need to be addressed to encourage them to invest in improvements in their operations. Measures include capacity development, increasing access to inputs, and efforts to link smallholders to markets. Viable social-protection systems (e.g. social assistance and social insurance, which can include subsidized agricultural or other insurance) can also mitigate risks. De-risking investments in smallholders and small and medium-sized enterprises requires an integrated approach that addresses risks for both investors and investees. Helpful examples are available in the agriculture sector – such as for cocoa in West Africa.[417]

Benefit-sharing mechanisms for REDD+ are emerging, but full implementation is limited despite readiness efforts in many developing countries

Benefit-sharing is "the intentional transfer of monetary and nonmonetary incentives (goods, services or other benefits) to stakeholders for the generation of environmental results (such as GHG emission reductions) funded by revenues derived from those results".[418] Although there is no universal definition, the concept of REDD+ benefit-sharing refers to the set of institutional means, structures and instruments aimed at enabling the distribution of benefits from REDD+ programmes among stakeholders. According to Bertzky *et al.* (2021), most countries are still at an early stage of development in their benefit-sharing mechanisms (Figure 23),[419] but good practices and key success factors have been identified from existing mechanisms. The slow uptake is due in part to the limited financing channelled through RBPs. ■

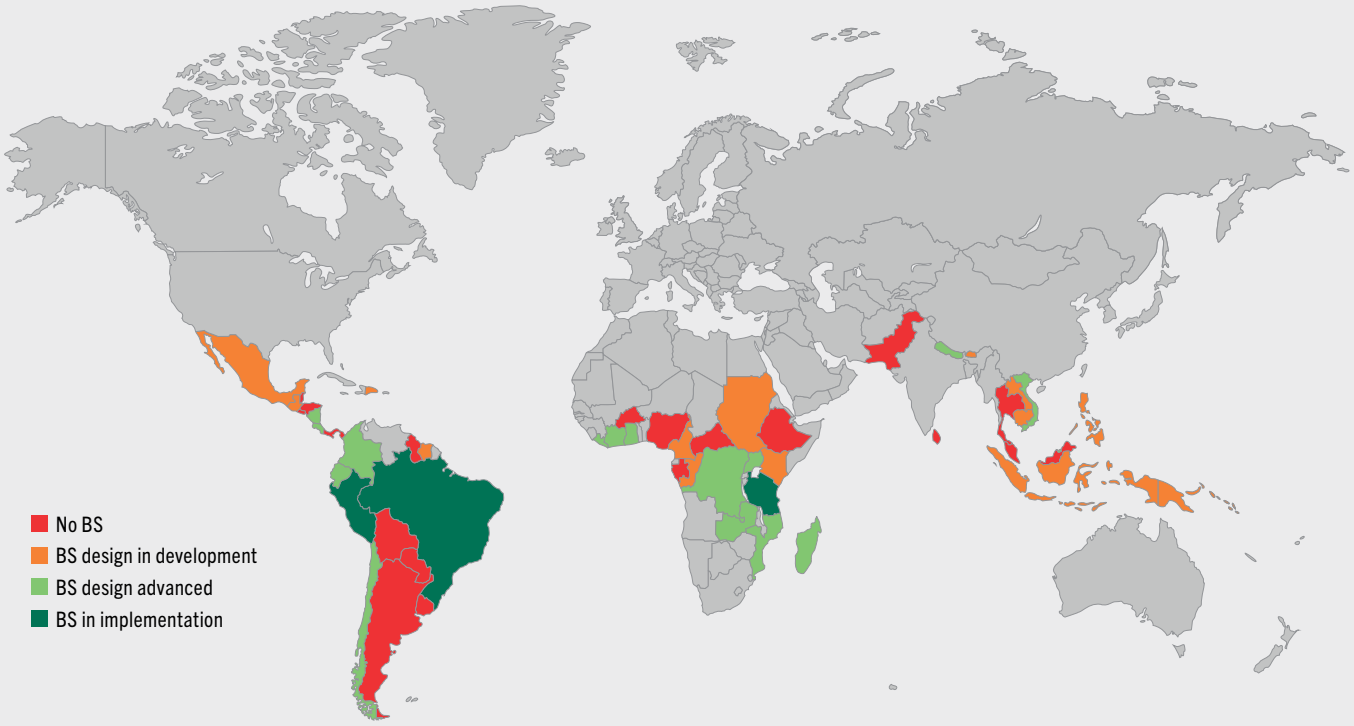
BOX 27 TREE COLLATERAL IN ASIA – TAPPING INTO FOREST SMALLHOLDER WEALTH

In Thailand, the current value of standing trees is used as part of loan collateral arrangements for smallholders organized through local groups called tree banks.[412] In Indonesia, a public programme enables smallholders to use their trees as collateral for loans to extend rotation periods and thus avoid premature harvesting.[413] In the Lao People's Democratic Republic, the availability of plantation certificates for smallholders enables access to microloans from a rural savings and credit union. These certificates are accepted by sawmills or intermediaries to back advance payments for the plantations two years before harvest.[414] In India, smallholders can receive loans for plantation establishment from financial institutions, with timber companies providing buyback guarantees and backing such loans as guarantors.[415]

BOX 28 TREES FOR GLOBAL BENEFIT – A SCHEME FOR BUILDING FARMER ASSETS BASED ON THEIR ECOSYSTEM SERVICES

The aim of the Trees for Global Benefit programme coordinated by Ecotrust in Uganda is to scale up the positive impacts that small and medium-sized enterprises and smallholders have on forest ecosystems. It seeks to aggregate ecosystem services provided by small farmer-led initiatives to restore tree cover and sustainably manage forests, sell these to international markets and distribute the proceeds to the farmers and enable them to access productive loans from formal financial institutions. Such loans are then used to strengthen sustainable agricultural and forest-based activities, such as honey production and the expansion of reforestation activities. More than 10 000 farmers are participating in the programme on more than 8 000 ha of land. In 2019, carbon credit sales to private entities generated 70 percent of the total financial flows (USD 2 million) in Trees for Global Benefit.[416]

FIGURE 23 STAGE OF DEVELOPMENT OF BENEFIT-SHARING MECHANISMS UNDER REDD+ IN THE 54 COUNTRIES SUPPORTED BY UN-REDD, THE FOREST CARBON PARTNERSHIP FACILITY AND OTHER INITIATIVES



NOTE: BS = benefit-sharing.
SOURCE: Bertzky, M., Canosa, O., Koch, A. & Llopis, P. 2021. *Assessment report – Comparative analysis of benefit-sharing mechanisms in REDD+ programs*. World Wide Fund for Nature. (also available at https://wwfint.awsassets.panda.org/downloads/wwf_assessment_report_redd__programs_v4.pdf).

SENEGAL
Women of the association Japo Ande Liggeye preparing the soil in order to plant a mango tree.
©Benedicte Kurzen/ NOOR for FAO

CHAPTER 5
SMALLHOLDERS, LOCAL COMMUNITIES AND INDIGENOUS PEOPLES ARE CRUCIAL FOR SCALING UP IMPLEMENTATION OF THE FOREST PATHWAYS

HEADLINES

➔ **The involvement of smallholders, local communities and Indigenous Peoples in the forest pathways is essential**. Such actors own or manage at least 4.35 billion ha of forest and farmlands worldwide; according to one study, smallholders produce farm and forest products worth up to USD 869 billion to USD 1.29 trillion per year.

➔ **Local actors can be highly effective – and cost-effective – forest managers**. For example, an estimated 91 percent of indigenous and community lands are in good or moderate ecological condition. Much of the change needed to scale up the forest pathways and support green recovery will need to happen locally and provide local actors with tangible benefits.

➔ **Customary forest rights are increasingly recognized in statutory laws, although progress has not been uniform**. Robust forest rights and the sound implementation of community-based forestry can help achieve green recovery, and statutory rights to high-value resources such as trees for smallholders can encourage green value chains.

➔ **Local producer organizations and other relevant groups can help enable the three forest pathways but require support**. More than 8.5 million social cooperation groups exist worldwide; they provide platforms for cooperation and innovation, and their influence in forestry is growing.

➔ **Increasing capacity and co-producing knowledge with smallholders, local communities and Indigenous Peoples would help scale up the three forest pathways**. Identifying and capitalizing on diverse sources of knowledge and new technologies can facilitate innovative and inclusive solutions grounded in local systems.

5.1 FOREST-BASED PATHWAYS NEED TO BE ATTRACTIVE TO LAND USERS

Smallholders, local communities and Indigenous Peoples own or manage at least 4.35 billion ha of forest and farm landscapes. Smallholders generate up to USD 1.29 trillion annually

According to a study by Lowder *et al.* (2021), there are more than 608 million farms worldwide, more than 90 percent of which are family farms[n] (of all sizes) occupying 70–80 percent of farmland – these farms account for an estimated 80 percent of world food production. Farms less than 2 ha in size comprise 84 percent of all farms and operate on 11 percent of the world's agricultural land; they produce an estimated 35 percent of world food production. About 80 percent of farms in low- and lower-middle-income countries (located primarily in East Asia and the Pacific, South Asia and sub-Saharan Africa) are less than 2 ha

n Lowder *et al.* (2021) define "family farms" as farms held by an individual, group of individuals or household whose labour is mostly supplied by the family. The same source defines "small farms" as farms with less than 2 ha. *Source*: Lowder, S.K., Sánchez, M.V. & Bertini, R. 2021. Which farms feed the world and has farmland become more concentrated? *World Development*, 142: 105455. https://doi.org/10.1016/j.worlddev.2021.105455

in size; they operate on 30–40 percent of land, a much larger share than in other regions.[420]

Another study concluded that, of the approximately 9 billion ha of land worldwide comprising forest and farm landscapes, an estimated 4.35 billion ha is controlled (owned or managed) by smallholders, local communities and Indigenous Peoples.[o,421] As huge as this area is, it is likely to be an underestimate (estimates vary widely depending on the methodology used). According to another estimate, smallholders[p] generate a gross annual production value of USD 869 billion to USD 1.29 trillion per year.[422] In many countries, 80–90 percent of forest enterprises are small or medium-sized, which generate more than half of forest-related employment.[423,424] Thus, smallholders, local communities and Indigenous Peoples will be crucial in the uptake of the three forest pathways and hence a green recovery and moves towards sustainable economies.

There is strong evidence that deforestation is lower on Indigenous Peoples' and local community lands, given the right incentives

Indigenous Peoples manage about 40 percent of all terrestrial protected areas and ecologically intact ecosystems worldwide.[425] Deforestation rates tend to be lower on Indigenous People's lands than in surrounding forests, including in protected areas, due to (among other reasons) cultural factors, traditional knowledge, strong governance, forest incentive policies, PES support, the low profitability of agriculture, and limited accessibility.[426,427,428,429,430] Studies also show that ensuring indigenous and tribal land rights could be highly cost-effective for halting deforestation and slowing climate change.[431,432,433,434,435] For example, it is estimated that securing indigenous lands in Bolivia (Plurinational State of), Brazil and Colombia would cost less than 1 percent of potential revenues from carbon storage alone.[436]

Ninety-one percent of Indigenous Peoples' and local community lands have no, low (i.e. less than 10 percent modified by humans) or moderate (>10–40 percent modified) human modification or are in good or moderate ecological condition.[437] A review of 24 countries found that indigenous and local communities customarily hold and use 958 million ha of land but have legally recognized rights to less than half this area.[438] Their lands store at least 253.5 GtC and thus constitute globally significant carbon sinks and reservoirs; 52 percent of this stored carbon is on lands that are not legally recognized, however.[472]

The devolution of forests to local communities more broadly has not produced consistently positive results in reducing deforestation and advancing restoration,[439] with success often depending on the extent to which legal frameworks are implemented, institutional capacity at the community level, the level of state support, and other factors, such as social capital.[440,441,442] There is evidence that smallholders with secure tenure tend to make longer-term investments in their lands and forests (e.g. in improving forest governance, tree-planting and managing soil and water) compared with those with no or short-term tenure security.[443] This may depend on the capacity to do so, however: a recent study in Indonesia, where a large programme of community titling is underway, found that such titling aimed at conservation did not decrease deforestation (and may have increased it) due largely to a lack of community-level institutional capacity and the economic opportunity costs of conservation. Community titling in timber production zones did decrease deforestation, however (from a higher base), which, according to the study's authors, was indicative of increased efforts to restore forests for timber production.[444] ■

o Because the definition of smallholder varies from country to country and region to region, we refer to all smallholders here as single household/family holdings (as opposed to those held by corporate entities). *Source*: Gilmour, D.A. 2016. *Forty years of community-based forestry – A review of its extent and effectiveness*. FAO Forestry Paper No. 176. Rome, FAO. (also available at https://bit.ly/3B1F5IH).

p The definition of "smallholder" in this source is unclear. Verdone, M. 2018. *The world's largest private sector? Recognising the cumulative economic value of small-scale forest and farm producers*. International Union for Conservation of Nature (IUCN), FAO, International Institute for Environment and Development and AgriCord.

5.2 SECURING RIGHTS IS ESSENTIAL IF SMALLHOLDERS, LOCAL COMMUNITIES AND INDIGENOUS PEOPLES ARE TO DELIVER LOCAL RECOVERY VIA THE FOREST PATHWAYS

Systematic reviews of land and forest property reforms have found generally positive or mixed impacts on agricultural productivity, income consumption and capital.[445] Interventions that devolve more limited rights (e.g. only access or withdrawal but not management or alienation rights) are less likely to alleviate poverty than the devolution of more extensive rights.[446] Moreover, there is substantial social differentiation in the impacts of tenure reform (e.g. by ethnicity and gender).[447]

Tenure reform continues to face challenges in many countries, such as states adopting laws but not implementing them, or retaining control of high-value forests[448] and decentralizing low-value degraded forestland in need of restoration;[449] the persistent marginalization of women's rights to resources;[450,451] and differential livelihood impacts on ethnic minorities and other marginalized groups. Nevertheless, tenure and property rights can act as levers of change[452] and, in some contexts, reforms can facilitate locally led recovery and the local development of value chains.

Many countries recognize customary rights in statutory laws or have devolved new rights on public lands. This has been done by either formalizing customary tenure or through various collaborative, community and smallholder programmes on public lands. More than 90 percent of Africa's rural people gain access to land through customary or formalized new-customary institutions. One-quarter of sub-Saharan Africa's land area – 740 million ha – is made up of communal property such as forests, rangelands, swamps and deserts.[453] Approximately 45 percent of intact forests in the Amazon are on the customary lands of Indigenous Peoples.[454] The trend in devolving rights is partly in recognition of community-based forestry (all forms of forestry allowing people's participation) and its potential to move towards sustainable forest management and improve local livelihoods, particularly where the centralized state management of forests has failed to control deforestation and degradation.[455]

States have been providing communities with more robust rights in recent decades, including by recognizing rights over ecologically intact forests rather than mainly degraded forests; allowing fuller governance roles rather than only some responsibilities such as monitoring and patrolling; and granting commercial rights to wood products and NWFPs rather than the subsistence use of NWFPs only.[q] Since 2012, international endorsement of the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security has provided significant additional validation and support for the strengthening of customary tenure globally.[456]

These significant shifts in national policies have increased the ability of smallholders, local communities and Indigenous Peoples to sustainably harvest high-value forest resources and derive income from PES, REDD+ and carbon credits, thereby giving them both sustained benefits and incentives for better forest governance and management. Progress has not been uniform, however: not all states recognize customary rights or provide forest rights to communities; some have adopted laws but not implemented them; and some have recognized local stakeholder rights but subsequently retracted them.[457]

q Based on community-based forestry and forest tenure assessments conducted in 23 countries globally between 2016 and 2020 using FAO frameworks. A cross-country analysis of findings is presented in: Aggarwal, S., Larson, A., McDermott, C., Katila, P. & Giessen, L. 2021. Tenure reform for better forestry: an unfinished policy agenda. *Forest Policy and Economics*, 123: 102376. https://doi.org/10.1016/j.forpol.2020.102376

Accelerating the formalization of customary and collective rights is crucial for protecting forests and mobilizing resources for recovery and development

National-level policymakers can use rapid and low-cost means to provide robust and secure tenure for millions of rural households without the need for major legal reforms. In a number of countries, customary forest rights are already recognized in statutory laws but have not yet been formalized.

Approaches exist to rapidly formalize rights where statutory laws already recognize them. Countries can develop regulations giving recognition to customary lands without the need for titling while also encouraging the registration of such lands through simplified processes to prevent encroachment. Ghana, Papua New Guinea, Sierra Leone and Zimbabwe allow the recognition of customary rights without requiring titling. Mozambique, Timor-Leste and the United Republic of Tanzania recognize rights but encourage registration.[458]

India recognizes customary collective tenure to forests in its Forest Rights Act, 2016; under this Act, customary governance (community forest rights) can be formalized on an estimated 34.6 million ha – close to half the national forest area – but only 10.4 percent (3.6 million ha) has been so formalized, mainly through support from non-governmental organizations.[459]

Governments can simplify land registration processes by reducing the number of steps required, and there are many ways in which this can be done. For example, governments can eliminate requirements for official or historical records and instead recognize oral testimonies validated by neighbouring communities and local leaders as proof of land claims; help negotiate overlapping claims; allow communities to submit simple land-use or community development plans rather than the complex forest management plans required of industries; recognize indigenous and local communities as legal entities rather than requiring them to incorporate themselves as associations; and, where rights registration systems are lacking, provide local registries in place of regional and national land offices. For example, Madagascar's Land Law allows local claimants to register lands through community land commissions.[460]

To speed up formalization, some governments use a "tenurial shell" approach, which recognizes the outer boundaries of multiple adjacent communities and allows them to manage land and resources for diverse purposes within these boundaries.[461] This approach can help prevent encroachment by outsiders and facilitate the recognition of seasonal and secondary resource rights, particularly those of women, transhumance communities and other vulnerable groups. It can work well where intra- and inter-community conflicts are few, traditional institutions are strong, traditional authorities are able to secure tenure for its members and resolve internal conflicts, and national governments can enforce such rights; Ecuador and Colombia have used this approach to recognize the authority of Indigenous Peoples to manage forest reserves on their lands.[499] Governments may require resource management plans and evidence that resources are being managed.

Countries recognize rights through diverse other approaches suited to varied ecological contexts and local needs. For example, Brazil recognizes perpetual territorial use rights in some areas, and it has designated some other areas as extractive reserves for the commercial use of specific NWFPs. India recognizes the customary rights of settled communities and smallholders as well as appropriate rights for pastoralist groups, semi-nomadic hunter-gatherers and those practising shifting cultivation, including in wildlife sanctuaries and national parks.[462]

In some cases, processes to formalize rights have been targeted at areas where forests are under particularly high pressure and where tenure formalization can yield important benefits. For example, titling carried out in the Peruvian Amazon involving more than 1 200 communities of Indigenous Peoples led to a significant reduction in illegal logging and improvements in forest conservation within two years.[463]

A range of new, low-cost technologies are being used to help secure community tenure in remote areas through participatory approaches.

Drones, global-positioning-system-enabled smart phones and tablets, mobile apps, open-source software and crowd-sourced data-collection methods can significantly reduce the cost of surveying and associated mapping exercises.[464,465] Finally, respecting the rights of Indigenous Peoples and local communities to free, prior and informed consent, as per the UN Declaration on the Rights of Indigenous Peoples, and consultation throughout the process, can help ensure that the approaches identified are appropriate to the local context.

Nearly all countries have some form of community or collaborative forestry regime.[466] A recent assessment of 23 countries showed, however, that legal provisions and implementation were weak in most or implemented in only a small proportion of national forests.[467] Nineteen of the 23 countries provided indigenous and local communities with few or no legal protections against the reduction or elimination of land and forest rights. Twenty-two had regulatory frameworks that hindered the capacity of communities to benefit from their recognized rights, and only one (China) supported the development of community-forest-based economies.[468]

Regardless of the status quo, governments can improve forest governance and restoration efforts by prioritizing the devolution of forestry programmes such as those involving FLR and REDD+. Formal community-based forestry initiatives can:

- build on customary rights and local tenure arrangements to avoid conflicts between and among multiple primary, seasonal and secondary forest users;
- devolve rights by law and in practice to land controlled by communities, including those with good-quality forests;
- ensure that rights go beyond subsistence needs to the use and management of high-value resources;
- enable the generation of forest-based income and thereby recovery, which can help prevent out-migration;
- simplify regulations and remove regulatory barriers (such as restrictions on harvesting that complies with management plans) to facilitate the use of resources, processing and value-adding;
- invest in alternatives to large private sector concessions, such as community-owned forests and community-plantation-based concessions (e.g. for timber, fuelwood, charcoal and high-value resources) and community licences for timber and biomass energy;[469]
- ensure that rights are not eliminated or reduced arbitrarily (which is a disincentive for good forest management); and
- where the effectiveness of community-based forestry is uncertain, grant longer-term rights based on performance, as practised in the Gambia.[470]

Strengthening smallholder tree rights and reducing regulatory barriers can encourage smallholder adoption of restoration and agroforestry

Gains in tree cover (in countries as diverse as China, Sweden, the United Republic of Tanzania and Viet Nam) are often driven by private smallholders for commercial purposes, but smallholder land rights are uncertain in many countries. For most smallholders, tree (and carbon) rights are even more uncertain than land rights. For example, many African states retain ownership rights over trees on farms, even those planted by farmers.[471] Although this is changing gradually, most countries that give farmers tree rights also heavily regulate tree use and management on private lands, especially for naturally regenerated trees. Governments also provide farmers with large subsidies to cultivate staple crops, leading to forest loss[472] and incentivizing rural households to shift away from agroforestry towards annual crops. Bottlenecks in wood product supply chains may discourage farmers from engaging in agroforestry. In India, for example, most states allow farmers to plant and harvest trees on their farms, but many farmers with forest areas and approved management plans still choose to plant crops rather than trees because of the bureaucracy involved in treefelling and transport.[473]

Forestry programmes might recognize these limitations that undermine landscape restoration but address them inadequately. For example, the Restoration Opportunities Assessment Methodology (see Box 11) provides countries with

BOX 29 RE-GREENING THE NIGER BY ADVANCING TREE RIGHTS FOR FARMERS

A presidential decree in the Niger in July 2020 awarded farmers formal ownership rights over naturally regenerating trees on private lands.[477] This came after 30 years of the gradual strengthening of tree tenure rights in the Niger. Tree-planting efforts in the 1970s and early 1980s failed because of low tree survival rates and a lack of local participation. In 1983, the Government of the Niger began encouraging farmers to regenerate naturally occurring trees on their farms, starting in the Maradi region, and removed restrictions that prevented farmers from managing these trees. Seeing the success of this approach, the government enhanced rights to protect, manage and benefit from on-farm trees in the 1993 Rural Code and strengthened rights to the subsistence use of trees on customary lands and forest reserves under the 2004 Forest Code. Meanwhile, projects worked with customary institutions to privatize rights to trees. Farmer-managed natural regeneration rapidly paved the way for re-greening nearly half of all cultivated land (5 million ha), benefiting about 30 percent of the population with improved crop yields and the production of woodfuel, fodder and other products and reducing conflict over scarce resources and poverty-driven migration.[478] Women, widows and the landless poor also benefited from the restoration of degraded areas, gaining access to land and increasing their incomes.[479] Natural regeneration helped restore ecological processes and biodiversity compared with restoration involving nursery-grown tree stock.[480]

guidance on assessing tenure and land governance in forestland tenure planning processes, but an assessment found that reports from countries in which the methodology has been implemented do not include systematic assessments of rights to trees, forests or land in statutory or customary laws.[474] Governments can promote restoration and agroforestry initiatives through a range of measures. For example, they could provide smallholders with secure rights to land, trees and carbon; they could also use forestland allocation mechanisms or conditional leases in which farmers (particularly the landless and tenant farmers) are offered long-term, secure rights to trees and tree products in exchange for adopting good natural resource management practices, including sustainable agroforestry.[475] Where farms are small and fragmented, they could also provide land consolidation measures or regulations that allow landholders to combine lands into joint holdings, incentivized by special rules and taxes,[476] and they could remove regulatory constraints to sustainably use and manage trees on private lands (Box 29). In China and Viet Nam, governments provided comprehensive support to small-scale forest enterprises over long periods, with huge positive economic and environmental impacts (Box 30). ■

5.3 STRENGTHENING LOCAL PRODUCER GROUPS IS A MEANS FOR ENGAGING SMALL-SCALE ACTORS IN LOCAL RECOVERY AND DEVELOPMENT

Policy and legal reforms are important for providing local actors with tenure security. Strengthening existing local producer and other social groups and empowering them is crucial for the change needed for recovery and the development of resilient local economies.

BOX 30 ENABLING POLICIES FOR SMALLHOLDER FORESTRY IN CHINA AND VIET NAM

Prompted by severe forest degradation, China initiated forest tenure reforms in the 1980s by devolving forest tenure rights to communities and then allowing communities to allocate forests to individual households. More than 180 million ha of collective forestland was transferred to households for a 70-year period.[481] Full rights were granted to wood and non-wood products for subsistence use and sale and, over time, all taxes were eliminated, including on wood sales. The government set up service centres to facilitate the transfer and registration of forestlands, conduct forest asset appraisals, provide market information and microcredit, issue logging permits, broker trade, and provide technical support and extension services and skills training.[482] These reforms led to an increase in forest cover, and smallholder forests are now meeting a significant portion of domestic demand for wood; China produced 40 percent of wood-based panels and 27 percent of paper and paperboard globally in 2019.[483] Although the government emphasized timber production, the reforms also enabled communities to collectively scale up their commercialization of non-wood forest products.[484]

In Viet Nam, where smallholders own around 1.97 million ha of forest plantations and contribute 60 percent of the industrial wood supply, smallholder tree farmers have been supported by favourable policies on land allocations, land tenure, tree ownership, foreign investment, regulations and trade, as well as by favourable stumpage prices, low-interest credit and the private sector provision of seedlings and technical support.[485] As a result, they are contributing to rural development, employment generation and the strengthening of rural livelihoods.[486,487]

More than 8.5 million social cooperation organizations exist worldwide, representing important social capital. They provide platforms for cooperation and innovation

Social cooperation organizations are created to address, for example, land management, water, pastures, integrated pest management, supporting services and innovation platforms. Their number has increased worldwide from 500 000 in 2003 to 8.5 million in 2018 (in 55 countries).[488]

Three main types of social cooperation organization exist that are involved in forest management. One comprises groups such as community forest management committees, community forest user groups formed to protect user rights, and producer associations and cooperatives built to provide business and financial services to members. Boosted by forest policy reforms in the early 1990s, such groups have become important in many countries. About 30 000 forest user groups have been formed in Mexico.[489] In the Democratic Republic of the Congo, 109 community forest management committees have become functional since the signing of a community forestry decree in 2014 and now manage 2.05 million ha of forest. In the United Republic of Tanzania, 45.7 percent of forestland is owned by communities, 20 percent under community management arrangements; about 9.8 percent of the rural population is participating in community-based forest management and 8.4 percent is involved in joint forest management. In Indonesia, policy reforms are underway to expand social forestry to support community rights in forests from less than 1 percent (1.1 million ha) to over 10 percent (12.7 million ha) of the country's forest resource.[490] Forestry-based social organizations are also common in many industrialized countries: for example, nearly half of Sweden's 240 000 forest owners are members of a forest owner association, managing a total of 6.21 million ha.

A second type of cooperation organization is associated with social movements. In Colombia, Nicaragua and Peru, for example, such organizations have already helped advance legal reforms to strengthen rights and remove regulatory barriers.[491] Increasingly, federations of community forestry and forest and farm producer organizations, such as those in the

BOX 31 GHANA FEDERATION OF FOREST AND FARM PRODUCERS

The Ghana Federation of Forest and Farm Producers (GhaFFaP) was launched in 2020 with support from the Forest and Farm Facility and already represents more than 1 million smallholder producers. GhaFFaP has developed four strategic initiatives: (1) a national dialogue series (focusing on access to finance and market); (2) the sustainable financial transformation of forest and farm producer organizations using a village savings and loans scheme; (3) the Green Ghana initiative to promote environmental campaigns and integrated landscapes; and (4) the Charcoal Producers in Forest Landscape Restoration initiative to promote sustainable charcoal production. GhaFFaP is also involved in global multistakeholder platforms and national partnerships with the purpose of raising the voice of local producers at the national and international levels.

SOURCE: FAO.

Gambia, Guatemala and Nepal, are advocating for reforms in favour of local actors.[492,493] In the case of Nepal, the Federation of Community Forestry Users Nepal, which was founded in 1995 and now has about 8.5 million forest users, has become a powerful political force committed to promoting and protecting community and forest user rights in natural-resource governance.[494] Recently, federations of forest and farm producer organizations have used their capacity for collective action to mitigate the impacts of the COVID-19 pandemic on forest communities and their producer organizations. Case studies conducted in mid-2021 show the crucial role played by forest and farm producer organizations in Bolivia (Plurinational State of), Ecuador, Ghana (Box 31), Madagascar and Nepal.[495]

The emergence of "jurisdictional approaches" has led to the development of a third type of social cooperation organization aimed at addressing deforestation and forest degradation inclusively. Jurisdictional approaches combine public and private actions at the local level to address landscape-level and value-chain challenges. Originating in efforts and funding associated with REDD+, such approaches seek to align governments, businesses, non-governmental organizations, local communities and other stakeholders around shared goals of conservation and sustainable value-chain development at the local political level (where most land-use decisions are made). A study by Stickler *et al.* (2018) identified 39 jurisdictions (in 12 countries) representing 28 percent of the world's tropical forests that have made commitments on implementing a low-emissions development agenda in a jurisdictional approach format.[496] Of the initiatives analysed, 19 jurisdictions had reduced their deforestation rates compared with projected subnational forest reference levels.[497] Various initiatives and projects aimed at implementing REDD+ and promoting integrated development and sustainable landscapes now claim to have adopted jurisdictional approaches. The green growth strategy of the Brazilian state of Mato Grosso, for example, involves collaboration among government, businesses and civil society to achieve zero deforestation and eliminate forest degradation. This three-faceted "produce, protect, include" strategy aims to increase the production of agricultural commodities, conserve natural resources (including eliminating about 6 Gt of GHGs by 2030) and include smallholders and Indigenous Peoples in economic development.[498] Similar initiatives focusing on collective action exist in Indonesia and Malaysia. The Coalition for Sustainable Livelihoods, for example, was launched in September 2018 in North Sumatra and Aceh, Indonesia; it includes some of world's largest food companies.[499]

Local producer organizations and other social cooperation groups are crucial for the three forest pathways but require support. Investments in the social capital they represent tend to increase the level of local ownership by members, lead to the sustainability of the process when external support ends, and have positive outcomes in terms of forest condition and livelihoods. Some governments have established financial programmes and policies targeting smallholders, local communities and

BOX 32 INVESTING IN SMALLHOLDER FORESTRY IN GUATEMALA – A PATHWAY FOR RURAL GREEN ECONOMY AND GREEN RECOVERY

In 2010, the Guatemalan Congress created the Forest Incentives Programme for Smallholders (PINPEP) with the aim of enabling smallholders to participate in sustainable forest management through cash payments, reduce deforestation, increase forest cover and restore degraded areas while promoting inclusion and improving the livelihoods of vulnerable populations. PINPEP also seeks to recognize the claims of traditionally marginalized groups to tenure and property rights, particularly smallholders and communal and indigenous groups. PINPEP has become a powerful tool for public–private partnerships, boosting the rural economy and generating synergies; it is now one of the country's most important financial tools for advancing REDD+ and landscape restoration commitments. Investments have helped establish and maintain more than 139 000 ha of natural forests, forest plantations and agroforestry systems; benefited 300 000 households; and created an average of 5 900 jobs per year. Approximately 46 percent of the beneficiaries have been indigenous households, of which 43.4 percent of members were women.

SOURCE: FAO.

BOX 33 CHINA'S GRAIN FOR GREEN PROGRAMME

Launched in 1999, the Grain for Green Programme (GGP) is China's largest ecological restoration programme; it aims to convert marginal lands and steep slopes into forest and grassland to prevent soil erosion and desertification. The GGP has contributed to the successful restoration of 34.3 million ha of degraded land and farmland, achieved significant environmental improvements, increased farmer incomes and alleviated poverty. Nationwide, 41 million households have participated in the programme, and 158 million farmers have benefited directly.[500] The GGP has fostered local social capital and endogenous growth and empowered participating households through specific social protection elements, such as grain and cash subsidies and technical assistance.[501,502] Over 90 percent of participating households are covered by basic medical insurance and pensions.[503] The programme has established a registration system that confirms the ownership and use rights of converted lands and established forests, allowing households to receive income from timber and payments for ecosystem services.[538] Together with other ecological restoration programmes, the GGP has also established 21 000 cooperatives for poverty alleviation and afforestation, benefiting 1.2 million poor people.[504]

Indigenous Peoples, providing insights into how this might be done elsewhere. In Guatemala, the government has invested more than USD 215 million over ten years to support smallholders in the establishment of small-scale forest plantations, agroforestry systems and sustainable forest management (Box 32). In Ecuador, the government's Socio Bosque programme grants cash payments to forest communities for sustainable forest management and ecosystem services, leading to positive social and environmental outcomes including deforestation abatement, ecosystem restoration and increased local incomes. China's Grain for Green Programme (Box 33), for example, which works across a mosaic of landscapes and combines mutually supportive poverty alleviation, social protection and forestry goals for both local and public-sector actors, has demonstrated how building on social capital can bring multiple benefits. The International Model Forest Network is an international initiative to promote forest-based development through investment in local social capital (Box 34). ■

BOX 34 THE INTERNATIONAL MODEL FOREST NETWORK AND LOCAL FOREST-BASED DEVELOPMENT

A comparatively long-standing international initiative promoting forest-based development through local leadership and landscape governance is the International Model Forest Network, a voluntary community of practice comprising 60 model forests in 35 countries worldwide covering more than 73 million ha. Efforts range from supporting local food culture linked to forests in the Chocó Andino Model Forest in Ecuador to local sustainable wood labels in Italy.

SOURCE: International Model Forest Network. Undated. Landscapes, partnerships, sustainability [online]. [Cited 11 November 2021]. https://imfn.net/

5.4 INCREASING CAPACITY AND CO-PRODUCING KNOWLEDGE WITH SMALLHOLDERS, LOCAL COMMUNITIES AND INDIGENOUS PEOPLES WILL SUPPORT FOREST-BASED RECOVERY AND RESILIENCE

Extension, farmer-field-school approaches and peer-to-peer exchanges can strengthen local capacities and innovation

Contemporary approaches to forest education include extension, farmer-field-school approaches, peer-to-peer exchanges and business incubation[505,531] to provide smallholders, local forest-based businesses, local communities, Indigenous Peoples and forest workers with learning opportunities and access to technical support.[506,507,508] In many countries, however, forestry extension services have been weakened due to financial, political and structural constraints. Existing extension and development programmes are often rooted in technocentric approaches focused on pre-selected "best practices" that treat forest communities as passive learners. They also rarely involve farmers and local knowledge-holders in training development and thus inadequately address knowledge needs and gaps.

There are opportunities to shift this paradigm, strengthen forest knowledge and innovation, and increase the role of farmers and Indigenous Peoples in sustainable forestry, the integration of trees in agriculture and related value-chain and business development.[509,510] For this to succeed, investment is needed to bring back forest extension programmes that use people-centred approaches and aim to co-produce knowledge and develop soft skills,[511,512] such as through farmer field schools (Box 35).[513] Learning-by-doing approaches in community-based forestry also show promise, such as in Brazil[514] and Indonesia.[515]

Many smallholders, local communities, Indigenous Peoples and their organizations would benefit from additional support to innovate and gain greater access to value chains and markets, including through the use of digital tools, cooperation and public–private partnerships. Market closures and restrictions due to the COVID-19 pandemic have

BOX 35 FARMER FIELD SCHOOLS IN FORESTRY

For more than 30 years, farmer field schools (FFSs) have helped rural communities and smallholders innovate and build technical and social skills through participatory knowledge exchange.[551] FFSs use people-centred learning and participatory methods, including practical field exercises. Over 20 million farmers from 119 countries have graduated from FFSs since 1989.[516] A 2020–2021 stocktake of FFSs in forestry and agroforestry identified 15 major programmes across the tropics with over 200 000 graduates (FAO will publish the results of the stocktake in 2022). Common themes included integrated pest management in coffee, cocoa, citrus, mango and other fruit trees, plantation management, the use of trees in soil conservation, pastoral and rangeland management, timber and woodfuel production, and watershed and landscape management.

Drawing on the concept of FFSs, the farm business school (FBS) approach was developed to assist smallholder farmers to strengthen their business operations. An estimated 400 000 farmers (20–40 percent of whom are women) have been trained to date. FBSs, farmer marketing schools and related approaches continue to grow worldwide, with implementation in (for example) Indonesia, the Philippines and Thailand, where the business and entrepreneurial skills of about 10 500 smallholders have been improved.[517]

demonstrated the importance of digital tools and online marketing for rural producers.[518,519] With adequate support, such as capacity development in financial and organizational management, marketing and design, conducive procurement policies, and access to certification schemes and new markets, small farmers and producers can gain the skills, knowledge and means needed to overcome market barriers and establish profitable businesses and sustainable livelihoods. Public–private partnerships have demonstrated positive impacts in timber and non-timber forest production, forest conservation and reducing deforestation (see examples in Box 9).

Approaches that combine traditional and scientific knowledge and new technologies show promise, but challenges remain

Many projects that combine traditional and scientific knowledge and new technologies have enjoyed considerable success (e.g. Box 36). Nevertheless, challenges remain in bridging scientific and traditional knowledge systems, such as a lack of tools and approaches for engaging knowledge-holders and that reflect divergent worldviews, identities, practices, ethics and asymmetries of power and rights.[520] A recent report mapping eight Indigenous Peoples' food systems, including in forested landscapes, noted a total absence of educational programmes that integrated and built on indigenous values, beliefs and traditions in all studied sites.[521] Box 37 shows that considerable work is needed to develop approaches that incorporate traditional knowledge into formal and informal forest education.

Supportive policies are needed to enable forest curricula development based on solid partnerships, participatory processes and ethical engagement with traditional knowledge-holders and institutions. Forest education at all levels must be culturally and ecologically relevant to the needs of the people concerned to diminish the disconnection between the acquiring of knowledge and its local-level application. ■

BOX 36 REVITALIZING TRADITIONAL KNOWLEDGE FOR MANAGING WILDFIRES IN AUSTRALIA

Australian savannah landscapes have been actively managed for tens of thousands of years by Indigenous Peoples applying customary burning practices. The aim of the West Arnhem Land Fire Abatement project, which was initiated in 2006 and spanned more than 28 000 km^2 of indigenous-managed land, was to reinstate such customary fire management to abate wildfires. The project implemented an early-dry-season management programme that combines customary practice with contemporary tools such as aerial ignition, geographic information systems and remote-sensing technologies.[522] Over the first seven years of implementation, the project reduced emissions of accountable greenhouse gases (methane and nitrous oxide) by 37.7 percent relative to the pre-project ten-year emissions baseline.[523] As of early 2020, there were 76 registered savannah-burning projects, including 26 on indigenous lands.[524] The feasibility of adapting this emissions abatement methodology has been tested in fire-prone southern African savannahs in Botswana and Mozambique, with promising results.[525]

BOX 37 REVITALIZING FOREST EDUCATION

A global assessment of the status and needs of formal forest education undertaken by FAO, the International Union of Forest Research Organizations and the International Tropical Timber Organization in 2019–2021 found that forest education is often too narrowly focused and under-resourced and that forestry graduates are insufficiently prepared for contemporary workplaces.[526,527] The assessment identified an urgent global need to increase interest among young people to pursue forest education and careers, rebrand and revamp forest curricula, incorporate digital communication and information technologies, promote traditional forest-related knowledge systems, and prepare students for jobs in the green economy.

Building "future-fit" green economies based on forests and trees requires innovative ways of co-creating knowledge and innovation. This means connecting traditional and local knowledge and experience fruitfully with scientific and technical knowledge emerging in other contexts. Forest education systems and institutions can help raise awareness of the need to respect intellectual property rights when collecting, documenting and sharing traditional knowledge and empower communities to preserve and protect their own knowledge. They must also promote the intergenerational transmission of knowledge from elders to youth and recognize women as key repositories of many types of traditional knowledge.[528,529]

5.5 DIGITAL TECHNOLOGIES ACCELERATE ACCESS TO DATA, INFORMATION, KNOWLEDGE AND MARKETS

Increasing means exist for overcoming barriers to digital engagement

Government services and other tools are increasingly moving online; this is a general trend driven by technology and economies of scale. Smallholders, local communities and Indigenous Peoples are benefiting from the increased availability of digital tools such as smartphone apps and remote sensing, which improve access to information (e.g. forest monitoring, e-learning, weather forecasting, extension and advisory services, and real-time field data collection), finance (e.g. payments and digital credit records), business relationships (e.g. online marketing platforms) and markets (e.g. internet connections, voice and text messaging and digital platforms for product traceability).[530] Nevertheless, access to them is often a challenge in rural areas. Given the global trend of moving online, including rural communities in this "digital nation" is becoming imperative. The absence of means for participation could block the development of the entire forest sector. A lack of coverage is a major reason why the sector remains relatively conventional and the development and uptake of innovation has been slow, despite the considerable potential benefits that exist.

Many social, economic and demographic factors – such as education, income, ethnicity and gender – limit the use and adoption of digital technologies, particularly in rural areas and among the most vulnerable groups.[531] A lack of infrastructure and quality (connection speed), combined with high costs, also limit access for forest communities and rural populations in less-developed countries.[532] In Africa, only 25 percent of urban households and 6.3 percent of rural households have internet access.[533] Worldwide, 2.9 billion people are still unconnected, particularly in Africa, Asia, South America and the Pacific Islands. The Working Group on 21st Century Financing Models for Sustainable Broadband Development recognizes that, to address the critical issues of access, affordability and equality, new approaches are needed that support the development of digital infrastructure, especially where it would otherwise not be profitable.[534]

Another challenge is the cost of services and disparities in purchasing power. For example, voice and mobile data packages cost 3.2 percent and 2.9 percent, respectively, of per-capita gross national income in the Americas[r] but 12 percent and 11.4 percent in Africa.[572] Other challenges in sub-Saharan Africa include a lack of farmer involvement in the design of mobile apps, a lack of trust and transparency, the use of foreign languages, inadequate considerations of cultural contexts, low education and training, low commitment and collaboration, and bureaucracy.[535]

Investments in digital public goods[536] and public digital infrastructure[537] can help bridge the digital gap and overcome reluctance among service providers to invest in remote and unprofitable areas.[538,539] In Brazil, the government has developed a plan to increase internet adoption, particularly among rural youth; Bolivia (Plurinational State of) has implemented broadband access in strategic rural communities; and, in Chile, the government has subsidized infrastructure connections in more than 1 400 areas that had limited or no connectivity.[540]

r The UN Broadband Commission for Sustainable Development set as a target for 2025 that entry-level broadband services should correspond to less than 2 percent of monthly gross national income per capita by 2025. *Source*: UN Broadband Commission. 2017. *The State of Broadband 2017 – Broadband catalyzing sustainable development*. ITU/UNESCO. 104 pp. (also available at https://www.broadbandcommission.org/publication/the-state-of-broadband-2017/).

BOX 38 A LOCALLY DEVELOPED DUE-DILIGENCE SYSTEM IN VIET NAM

Assessing timber legality is necessary for ensuring that only legal or low-risk timber enters responsible supply chains and markets. In Viet Nam, the Handicraft and Wood Industry Association of Ho Chi Minh City (HAWA) has developed a technology platform to support transparency and due diligence for each seller–buyer transaction involving members of HAWA's due-diligence system. For domestic timber sources, real-time and georeferenced evidence can be uploaded together with the required documentation or verifiers. The HAWA team flags possible risks and makes information available to potential buyers. As well as providing an opportunity for forest owners to register their plantations and document their harvests, the platform facilitates and documents a transparent due-diligence process for transactions and sales along the timber supply chain.

SOURCE: FAO–European Union Forest Law Enforcement, Governance and Trade Programme. 2021. *Locally developed due diligence system launched in Viet Nam* | *FAO-EU FLEGT Programme* [online]. [Cited 11 November 2021]. https://www.fao.org/in-action/eu-fao-flegt-programme/news-events/news-details/ru/c/1414433/

Digital technologies can support farm and landscape-level planning, monitoring, production logistics and access to markets

The potential for digital technologies to change forestry is high. To date, the main developments have been in the inventorying and monitoring of forest resources; land-use planning and land-change monitoring; forestry production and machinery logistics; transport logistics and the traceability of forest products (Box 38); and business management and marketing support (Box 39). Box 40 provides an example of remote-sensing-supported planning of restoration. Multiple non-technical obstacles exist to the mobilization of digital innovations and scaling up their use, however.

Digital technologies can be useful in forest protection, such as by assisting in the detection of fire, illegal forest use, forest degradation and forest-cover change and for obtaining data on sustainable forest management. Geospatial forest-mapping products are becoming more accessible, as are excellent participatory mobile-phone global information system-activated forest monitoring products; even the camera function of smartphones is a valuable tool. More advanced approaches might involve drones (Box 41). Digital technology is becoming easier to use (and can encourage the involvement of youth). This, coupled with their increasing affordability, will make digital approaches more cost-efficient.

Information from public and private technical and extension services is becoming available online and as apps, including for various public services, making them more inclusive, especially for those who live far from physical service centres. E-services can cover many aspects of forestry, such as applications for logging and transport permits and ordering tree seedlings.

The rise of online marketing and sales in rural settings. Digital marketing and commerce have become more important in the pandemic. Many forest products can now be sold via e-commerce, including NWFPs. Digital online marketing events can help promote products, and mobile-assisted services are being tested to deliver products to customers.

Timber producers and traders in tropical countries have been severely affected by the pandemic, with cancelled orders and a wide range of logistical challenges, with associated impacts on livelihoods. Many micro, small and medium-sized enterprises have turned to digital solutions to facilitate market access

BOX 39 A WOMEN'S ASSOCIATION PRODUCES SUSTAINABLE CHARCOAL IN CÔTE D'IVOIRE

The Association of Women Producers and Traders of Secondary Forest Products (MALEBI) in Côte d'Ivoire produces and sells charcoal while also conserving natural forests through reforestation activities, capacity development and advocacy. MALEBI has a partnership with the state-owned company SODEFOR to manage 4 500 ha and help reforest a degraded part of the Ahua gazetted forest in Dimbokro. MALEBI involves hundreds of local village women and members of the Women's Federation of Dimbokro in planting native species such as *Cassia siamea* and teak (*Tectona grandis*). In 2018–2020, the FAO–European Union Forest Law Enforcement, Governance and Trade Programme and Resource Extraction Monitoring helped MALEBI develop a traceability mobile app, *Charcoal Trace*, using blockchain technology to track its charcoal along the entire value chain. MALEBI can now certify its charcoal's origin and sustainability.

SOURCES: Bottaro, M. 2021. *Women's participation in wood-based value chains in voluntary partnership agreement countries – MALEBI: Women at the forefront of sustainable charcoal production in Côte d'Ivoire – The experience of the FAO-EU FLEGT Programme.* Rome, FAO.
Eulalieguillaume. 2021. *La technologie Blockchain pour la bonne gouvernance du charbon de bois en Côte d'Ivoire* | by Eulalieguillaume | Gaiachain Lab | Medium [online]. [Cited 14 November 2021]. https://medium.com/gaiachain/la-technologie-blockchain-pour-la-bonne-gouvernance-du-charbon-de-bois-en-c%C3%B4te-divoire-94a5612bf5d4

BOX 40 AN APP FOR PREPARING STRATEGIC RESTORATION PLANS

In collaboration with various partners, FAO has developed Se.plan as part of its System for Earth Observation Data Access, Processing and Analysis for Land Monitoring, which combines ecological data on forest restoration with data on socio-economic costs, benefits and risks. The app, which is designed to support the preparation of strategic restoration plans in a given region, provides spatially explicit information on restoration suitability and the most relevant impacts for the restoration objectives of users. Se.plan covers 139 low- and middle-income countries, enabling users to consider the importance of factors such as cost (e.g. opportunity and establishment costs), risk (e.g. governance variables and demographic dynamics) and benefits (e.g. job creation potential).

SOURCE: System for Earth Observation Data Access, Processing and Analysis for Land Monitoring. Undated. *Se.plan – SEPAL documentation* [online]. [Cited 23 November 2021]. https://docs.sepal.io/en/latest/modules/dwn/seplan.html

while upholding timber legality commitments. In Indonesia, the Volunteers Alliance for Saving Nature (*Aliansi Relawan Untuk Penyelamatan Alam* – ARUPA), with help from FAO and motivated by a reported 80 percent increase in online trading of timber products during the pandemic, established Woodenasia, a legal-timber supplier e-platform that links forest communities to processors. The platform now features more than 200 timber, furniture and handicraft products produced by verified-legal micro, small and medium-sized enterprises.[541]

Traceability and transparency in forest-product trade. The origin and legality of timber and some non-timber products is especially important

BOX 41 USING DRONES FOR COMMUNITY FOREST MONITORING IN PANAMA

To strengthen natural resource management capacity in indigenous territories, FAO and the UN-REDD Programme implemented a community forest-monitoring project involving the use of drones. The training included preparing drone flight plans, arming and flying drones, image processing and mapping with high-resolution images. The main objectives were to identify changes in forest cover indicating deforestation or forest degradation and to monitor the status of crops and encroachments on territorial boundaries. The use of drones greatly facilitated these objectives.

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SOURCE: FAO. 2018. *e-Agriculture promising practice – Drones for community monitoring of forest*. Rome. 12 p. (also available at https://www.fao.org/publications/card/en/c/I8760EN/).

in tropical forestry, with certified legality mandatory for export to certain markets. Outdated paper records are giving way to digital options such as digital barcodes. Blockchain technology also has potential for facilitating transparency, reliability, security and traceability in the forest sector.

Well-established global certification bodies are starting to use blockchain in their business processes, such as the FSC, which is in the final stages of incorporating blockchain into its chain-of-custody certification with the aim of lowering costs, which might benefit smallholders. ■

BOX 42 WOMEN'S ENGAGEMENT IN LAND RIGHTS FORMALIZATION IN COLOMBIA

In Latin America, 33 percent of forests are managed under collective tenure regimes owned by communities, mostly Indigenous Peoples.[545] But despite legal provisions, the formalization of rights is slow, complex and costly, and little is known about how the reform processes involve and benefit women.[546,547] In Colombia, women's organizations have become active in formalization processes and policy discussions.[548] Cadasta (an organization providing technical services on land and resource rights) has worked with Aso Manos Negra, a women-run organization, to map and document community lands among Afro-Colombians in the Pacific region. Cadasta has developed systems and training to help women members collect data on women's economic activities and land use and track formalization processes. It also involves indigenous women in livelihood projects, resource-management planning, forest land-use planning and implementation activities.[549]

5.6 INCLUSIVE RECOVERY AND THE DEVELOPMENT OF LOCAL FOREST-BASED VALUE CHAINS NEEDS THE PARTICIPATION OF WOMEN AND YOUTH

Of the 1.35 billion people who live on less than USD 1.25 per day and depend on natural resources for employment, 829 million (61 percent) are women and girls.[542,543] Evidence from several countries shows that the inclusion of women and youth in natural resource governance has significant positive effects on forest conservation and development outcomes. For example, a study in East Africa and Latin America found that the presence of women in community forest governance structures significantly improved responsible behaviour and forest sustainability.[544]

Women's inclusion in forest resource governance is not always immediately viable. In contexts where participation is contingent on tenure rights, it is necessary – given that women's land and tree tenure rights are typically weak or non-existent – to facilitate the process of formally securing those rights and making women's voices heard (Box 42).

Youth have the potential to bring qualities that help make forest enterprises more efficient and productive – such as energy, enthusiasm, social media connectedness and risk-taking attitudes. They may also be more willing than some others to invest in ambitious projects and less likely to be held back by opposition from customary authorities.[550] Finally, they tend to have better access to education and information than previous generations, meaning they are well placed to introduce new ideas and organizational innovation, especially in terms of information technologies. Youth who migrate to urban areas can be sources of finance (through remittances), and those who return may directly invest new knowledge and finance (Box 43).[551]

Community-based organizations empower women and youth

In many countries, forest and farm organizations use youth and women engagement strategies to develop policies for the inclusion of these groups in forest governance and to strengthen their tenure rights. Their business models have advantages in creating job opportunities and access

BOX 43 YOUTH ORGANIZATIONS ENGAGING IN REDD+ POLICY DIALOGUES

The Forest Governance Learning Group (FGLG) in Indonesia started as a group of young, concerned foresters. Now a multistakeholder forum, it is building a network to support both FGLG Indonesia and the next generation of foresters. Members remain connected to the group as they progress professionally and act as advocates for community-led forest governance that respects the rights of local communities. Recently, FGLG Indonesia helped promote a multisectoral approach in Indonesia's national REDD+ strategy, aligning forest governance with policies on agriculture, land, mining and economic growth, with a focus on community forestry and local engagement. FGLG Indonesia supported consultations that led to significant improvements in sandalwood regulation in East Nusa Tenggara, new REDD+ learning tools, and decisive involvement in REDD+ and climate-change consultations on policies affecting Indonesian forestry.

SOURCES: International Institute for Environment and Development. 2014. *Forest Governance Learning Group – Indonesia – Supporting governance in REDD+ and community forestry.* London. (also available at pubs.iied.org/g03864). Siswanto, W. 2015. *Arguing forests – The story of FGLG Indonesia.* Country report. London, International Institute for Environment and Development. 35 p. (also available at https://pubs.iied.org/13577iied).

to markets for women, generating positive spillover effects in both household and group businesses, and increasing access to social services such as vocational trainings, childcare and maternity leave – all of which support women to participate in the labour market on a more equal footing with men.[580]

Forest and farm producer organizations are also pathways for business incubation to improve women's entrepreneurship. For example, it is possible to design gender-differentiated training programmes that fit with the available study hours of women and focus on the types of business that fit with their household situations. In India, the Self Employed Women's Association runs a management school for youth and other new managers on entrepreneurship, business development, market access, operations, new technology, product quality and standards certification, legal and financial issues, and business management.[552] Training more women extension officers can be particularly important in communities that prohibit male extension officers from interacting with women farmers.

Forest and farm organizations have facilitated the access of youth groups to land, conditional on performance,[553,554] and helped in the design of greener, more sustainable agroforestry businesses for youth.[555] Young people's enthusiasm and risk-taking attitudes make them important actors in new and potentially more productive farming systems, such as experimenting with diverse crops or trees, adopting new agroforestry and soil conservation measures and trialling new processing techniques. A recent knowledge-demand study of forest and farm organizations found that 59 percent of the 41 organizations surveyed across six countries had active youth programmes.[556] In Guatemala, for example, the rural agroforestry business school run by the umbrella cooperative Las Verapaces Cooperatives Federation emerged as a result of the many services the cooperative provides for its 37 member cooperatives and more than 100 other producer groups.[557]

Another area of increasing importance with links to women's empowerment is the provision of financial services, such as those provided by village savings and loans associations (VSLAs) and savings and credit cooperative societies, which are among

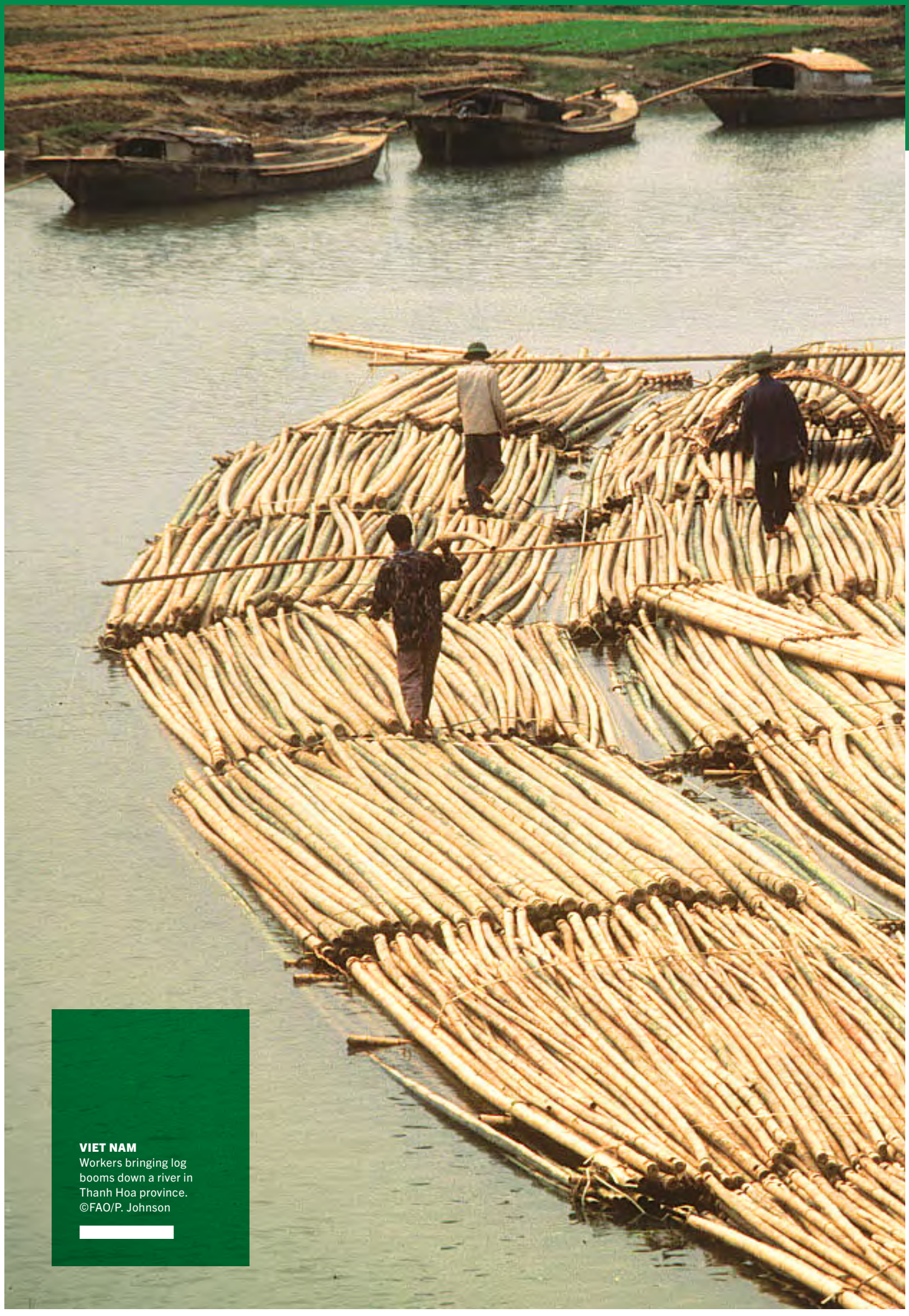
BOX 44 A WOMEN-LED COMMUNITY-BASED ORGANIZATION IN KENYA PROVIDING ACCESS TO FINANCE

Thiongote is a Kenyan women-led community-based organization made up of ten farmer groups engaged in forest and farm enterprise activities. It promotes sustainable agriculture and agroforestry, advances advocacy and lobbying, and creates partnerships and leverage for accessing markets and inputs.

Most members reinvest their profits in farm development or in education and loans. A collective fund enables members to bulk-purchase high-quality seeds and seedlings from government agencies at a lower price.

SOURCE: Bolin, A. 2020. *Women's empowerment through collective action – How forest and farm producer organisations can make a difference*. FAO and International Institute for Environment and Development. https://doi.org/10.4060/ca8713en

the fastest-growing cooperatives globally. Members are predominantly women, who are often underserved by formal banking.[580,558] Globally, VSLAs have more than 11.5 million members in 73 countries, accumulating more than USD 660 million in savings annually. Collectively, VSLAs provide access to finance for social and business purposes for 2 billion people – of whom a high percentage are rural women (Box 44).[559,560] ■



VIET NAM
Workers bringing log booms down a river in Thanh Hoa province.
©FAO/P. Johnson

CHAPTER 6
THE FOREST PATHWAYS – A MEANS FOR GREEN RECOVERY AND RESILIENT ECONOMIES?

HEADLINES

➔ **Most countries have taken steps along the forest pathways, although few appear to have coherent policies to promote all three and enhance their complementarity**. There is clear international momentum, and the time is right for bold strategies to scale up the pathways in ways that are mutually reinforcing and build resilience.

➔ **The three forest pathways carry economic, social, political and environmental risks**. For example, there is a risk that investors, including smallholders, will miss investing in more profitable ventures; conversely, the diversification offered by the forest pathways could increase the economic resilience of local actors.

➔ **Next steps could involve four possible actions**: (1) directing funding for recovery towards long-term policies aimed at creating sustainable economies and green jobs and further mobilizing private sector investment; (2) empowering and incentivizing local actors to take a leading role in the forest pathways; (3) engaging in policy dialogue on sustainable forest use as a means for simultaneously achieving economic and environmental goals; and (4) maximizing synergies among the three pathways and between agricultural, forestry, environmental and other policies and programmes and minimizing trade-offs.

6.1 THE ROLE OF FORESTS AND TREES IN GREEN RECOVERY AND RESILIENCE

There is widespread agreement that a green recovery is needed – not only from the pandemic but also in response to the environmental threats of climate change, biodiversity loss and the decline of ecosystem services. To date, however, efforts and investment towards economic recovery from the pandemic have largely ignored the potential of forests.

In many countries, forest conservation is not a high political priority, with rural people locked in daily struggles to feed their families. Economists can sometimes make a strong financial case for deforestation because growing annual crops can generate fairly reliable, regular revenue. On the other hand, forests play essential roles in the well-being of forest-proximate people, especially the very poor, and forest degradation

and loss reduces the safety-net function of forests. Moreover, there is ample evidence, as summarized in this report, that forests play crucial roles in regulating the local to global environment and therefore in supporting all people and life on Earth.

But does the world really need more trees and forests? To some extent, the answer to this question is context-specific; for example, some landscapes may already comprise a suitable balance among land uses, and others might tolerate a certain amount of further forest clearance. In general, however, the evidence presented in this report indicates that the continuation of deforestation and forest degradation is compounding problems associated with, for example, the emergence of infectious diseases, local to global climate change, damage caused by disasters, and the increasing scarcity of good-quality water. In addition, the world will clearly need a larger supply of materials in the future, and reducing the environmental impacts of their production, use and disposal will be essential if the world is to achieve sustainability. Wood and other forest-based materials, which are renewable and have other environmentally desirable qualities, will certainly have an important part to play.

Trees and forests offer solutions to many challenges, and one of their advantages is that they can address several simultaneously. This report explores three forest pathways with potential to assist in economic recovery from the pandemic while also addressing other problems. The pathways are (1) halting deforestation and maintaining forests; (2) restoring degraded lands and expanding agroforestry; and (3) sustainably using forests and building green value chains.

Alternative pathways for the future of food and agriculture exist and need to be considered carefully. FAO has done this in its Strategic Framework 2022–31[561] around the strategic ambitions of *better production, better nutrition, a better environment and a better life, leaving no one behind*.[562]

The three forest pathways build on FAO's ambition, vision and principles towards a better and more sustainable future. They are mutually supportive: for example, the role of wood and other forest products and services in a more circular economy will be enhanced by the creation of new forest and tree resources, restoration and agroforestry and by sustainably using retained natural forests; these, in turn, can create green jobs and income and thereby help underpin recovery and prosperity. Moreover, some solutions for better protecting the environment that seem to run counter to socio-economic interests today could have net benefits if current incentives are altered in ways that turn trade-offs into opportunities in which, for example, farmers can increase their productivity and incomes (e.g. through the adoption of innovative and green technologies, livelihoods and jobs) while also reducing risk. In addition to incentives, social-protection and social policies in general will be important for enabling resource-poor households to respond to such re-engineered incentives.

Not all trade-offs will disappear, and nor will all benefits remain at current levels. The distribution of benefits may change, too, given the ambition to "leave no one behind". Nevertheless, there is a strong case for much more emphasis on forests as part of the search for solutions. The long-term sustainable management of natural forests will ensure the provision of vital ecosystem services, including the conservation of biodiversity, which will support restoration efforts and help maintain resilience in the face of climate change. In an ideal world, a blend of forest protection, use and sustainable management will be integral to a clean and prosperous circular economy – supporting agriculture and improving the livelihoods of millions of rural people as well as the global population.

The three forest pathways are not new, but characterizing them in this way is a step towards considering them as an interrelated package that constitutes a holistic approach to addressing several local to global problems. It is demonstrably feasible to manage forests to produce multiple goods and services over very long periods without noticeable declines in productivity, food security or social and environmental values. In most regions, forestry is backed by more than a hundred years of practice and scientific inquiry and by traditional

knowledge accumulated over centuries. The key to scaling up the pathways is ensuring that the benefits and costs are shared equitably among stakeholders; this, in turn, will require governance approaches that are inclusive, transparent and backed by adequate oversight.

To some extent, the halting-deforestation and restoration pathways are prerequisites for, and will underpin, the sustainable-use pathway. Minimizing and reversing deforestation, establishing new forest resources and managing all forests sustainably will enable forest-based industries to meet an increasing proportion of the world's needs for materials and ecosystem services and, in so doing, generate green jobs and support economic development.

Pursuing the three forest pathways carries risks. For example, climate change could threaten the health and vitality of both natural and planted forests, and adaptive management will be important to mitigate this. There is an economic risk that investors – including smallholders – will miss investing in more profitable ventures by pursuing the forest pathways and that governments will spend scarce resources on forestry options with a significant risk of failure in the locations where they are tried. Conversely, the diversification of economic activities and income sources offered by the forest pathways, when adopted appropriately, is likely to increase the economic resilience of people at the local scale.

Yet another risk is the use of the forest pathways as a means for delaying action in other areas, especially in the context of climate change. The contributions of the forest pathways to (especially) climate-change mitigation need to be verifiable and not adopted as a means for avoiding necessary reductions of GHG emissions in other sectors.

Mitigating such risks seems feasible given existing knowledge, the increasing role of multistakeholder platforms in ensuring that all voices are heard, and the growing availability of digital means for generating near-real-time information on biophysical, market and social parameters. Much is still uncertain, however, about the impacts and outcomes of the forest pathways, and more work is needed to fully understand their costs, benefits and risks, especially those that are location-specific.

Many countries have already taken significant steps along the three pathways, such as by incentivizing forest conservation; improving forest MRV; investing in forest law enforcement, governance and trade measures and REDD+; tenure reforms; developing forest plantations; restoring degraded lands; and promoting agroforestry. Nevertheless, efforts aimed at scaling up the roles of forests and trees continue to face hurdles such as a lack of investment; environmentally harmful subsidies; a lack of engagement in decision-making; regulatory barriers, especially for smallholders; biophysical risks such as fire, pests and drought; and negative perceptions about sustainable forest use and the economic value of forests and trees in agricultural landscapes. Therefore, further efforts are needed for countries to develop policies that promote all three pathways and enhance their complementarity. ■

6.2 IS THE TIME RIGHT FOR GREEN RECOVERY?

There is clear momentum internationally for the three pathways. For example, the UN Decade on Ecosystem Restoration (2021–2030) has increased the visibility of forest restoration, and initiatives such as the Bonn Challenge and the New York Declaration on Forests have set ambitious restoration targets. The UN Decade of Family Farming (2019–2028) has drawn attention to the crucial role of family farmers in ensuring food security, improving livelihoods, sustainably managing natural resources, protecting the environment and achieving sustainable development. Some countries have developed policies to encourage more circular economies. The Glasgow Leaders' Declaration on Forests and Land Use has increased recognition of the role of forests in mitigating climate change.

There are significant private sector commitments on deforestation-free supply chains. International public and private financial resources are increasingly available, and policy innovations such as tax-related incentives are being tested to assist countries to move further along the pathways. Recent new pledges in the context of climate change, including support for Indigenous Peoples, offer additional opportunities for financing pathways.

Given this momentum, now could be the moment for bold strategies aimed at scaling up the three pathways. As a starting point, the analysis in SOFO 2022 indicates the following four key actions for national and subnational jurisdictions and international financing and processes:

1. **Direct existing and new funding for recovery towards long-term policies aimed at creating sustainable economies, including green jobs.** The forest pathways have considerable capacity to create green jobs and help develop sustainable economies. Funding decisions may depend on the cost-effectiveness of the pathways compared with other options, which, in turn, may hinge largely on ensuring an adequate policy environment and the strengthening of capacity at the local level.
2. **Empower and incentivize local actors to take a leading role in the forest pathways** – little will change *without* the involvement of smallholders, local communities and Indigenous Peoples, but much can change *with* them. Among other things, this action requires removing policy and bureaucratic hurdles, providing tenure security, supporting the development of local producer groups, and following through on key action 1.
3. **Engage in awareness raising and policy dialogue on sustainable forest use as a means for simultaneously achieving economic and environmental goals**, including biodiversity conservation and climate-change mitigation. In many countries, there is considerable negative sentiment towards the harvesting of trees in natural forests. It is undeniable that poor forest harvesting practices can contribute to the degradation and loss of natural forests; conversely, many forests have been harvested over long periods without noticeable declines in most values. Moreover, many natural forests are likely to increasingly require management interventions to ensure their long-term health in the face of climate change, fragmentation and other threats and to generate revenues for forest owners. With sufficient monitoring and safeguards to ensure that practices are compatible with sustainability, harvested natural forests can provide an important conservation complement to networks of protected forest areas.
4. **Maximize synergies among the three pathways, which are mutually reinforcing, and between agricultural, forestry, environmental and other policies, and minimize trade-offs.** For example, conserving the biodiversity in natural forests by halting deforestation will ensure the maintenance of genetic resources, while forest and landscape restoration and agroforestry can help mainstream biodiversity in the agriculture sector. The sustainable management of natural forests and the creation of new forest and tree resources will add to the availability of wood fibre for more circular economies. There are clear links between the expansion of agriculture and deforestation, and the pathways have important implications for sectors such as climate, biodiversity conservation and economic recovery.

One of the benefits of international dialogue is that countries, organizations and communities can learn from other experiences to more rapidly develop feasible strategies tailored to local conditions. Global platforms such as those provided by the SDGs, the UNFCCC COPs (especially the follow-up to the Glasgow Leaders' Declaration on Forests and Land Use), the Convention on Biological Diversity COPs and the United Nations Food Systems Summit, as well as private sector platforms and regional-to-global networks and platforms that connect local communities, municipalities, forest producer groups and others, will all play a role in finding adequate responses to current crises and the opportunities that forests and trees provide.

The Earth is astonishingly rich in biodiversity and natural resources, but current trends indicate an imminent danger of squandering this natural wealth, thereby endangering the world's diverse peoples and many other

species. More immediately, there is a need to recover from the hardship caused by the COVID-19 pandemic and to strive to ensure that all people are free from hunger and poverty. Humanity has the power to change environmental conditions at a planetary scale and an accompanying imperative to take action to maintain environmental conditions within boundaries that enable all life forms to flourish. Using nature-based approaches such as those involving trees and forests is a logical place to start in repairing the damage that has already been done to natural systems and in developing truly sustainable solutions to the problems and challenges articulated in this report. The beauty of trees and forests is that, if put to sustainable use, they can simultaneously perform many functions that benefit humanity and the planet as a whole – conserving biodiversity, mitigating and adapting to climate change, increasing resilience, generating green jobs, supporting food security and nutrition and ensuring an ongoing supply of materials. Indeed, it is only by restoring, conserving and sustainably managing forests that we will achieve sustainable agrifood systems and a *better life* for all. ■

GLOSSARY

Agroforestry. A land-use system that involves the use of perennial woody species with agricultural crops or livestock in a given space over a given period. The three main types of agroforestry system are: (1) agrosilvicultural (trees combined with crops); (2) silvopastoral (trees combined with animals); and (3) agrosilvopastoral (trees, animals and crops).

Bioeconomy. The production, utilization, conservation and regeneration of biological resources, including related knowledge, science, technology and innovation, to provide sustainable solutions (information, products, processes and services) within and across all economic sectors and enable a transformation to a sustainable economy.

Cascading use. The efficient utilization of resources by using residues and recycled materials to extend total biomass availability within a given system.[563] One of the aims of the cascading use of woody biomass is the maximization of value added by optimizing wood processing and extending total biomass availability, thereby also creating more jobs. The term can refer to a sequential use of woody biomass in which energy use is only considered after single or multiple material uses; that is, it excludes the direct energy use of harvested wood without prior material use (in wood products such as sawnwood, veneer and paper).

Circular economy. Refers to economic systems based on business models that reuse, recycle and recover (also known as the three Rs of sustainability or the 3R approach) materials in production, distribution and consumption processes for achieving sustainable development.[564] The concept can also be characterized as an approach that can reduce resource consumption by slowing, closing or narrowing natural resource loops.[565] The cascading use of woody biomass is one of the strategies for such economic models.

Deforestation. The conversion of forest to other land use independently of whether human-induced or not.[566]

Forest. Land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use.[2]

Forest degradation. The long-term reduction of the overall supply of benefits from forests, which includes wood, biodiversity and other products and services. In the Global Forest Resources Assessment, countries are requested to indicate the definition of forest degradation they use in assessing the extent and severity of forest degradation.[567]

Forest and landscape restoration. A planned process that aims to regain ecological integrity and enhance human well-being in deforested or degraded landscapes. It does not seek to recreate past ecosystems given the uncertainty concerning the past, the significantly altered conditions of the present as well as anticipated but uncertain future changes. However, it does seek to restore a forested ecosystem that is self-sustaining and that provides benefits both to people and to biodiversity. For this reason, the landscape scale is particularly important because it provides the opportunity to balance ecological, social and economic priorities.[568]

Forest ecosystem services. The benefits people obtain from ecosystems. These include provisioning services such as food, water, timber and fibre; regulating services that affect climate, floods, disease, wastes and water quality; cultural services that provide recreational, aesthetic and spiritual benefits; and supporting services such as soil formation, photosynthesis and nutrient cycling.[569] Forest ecosystem services are the ecosystem

services derived from forests – they include the production of ecosystem goods; climate and water regulation; soil formation and conservation; the generation and maintenance of biodiversity; pollination; pest control; seed dispersal; cultural values; and aesthetic beauty.[570]

Forest expansion. Expansion of forest on land that, until then, was under a different land use, implying a transformation of land use from non-forest to forest.[2]

Forest pathway. A development approach involving forests, of which the following three are identified in SOFO 2022: (1) halting deforestation and forest degradation as a crucial element for reversing the drivers of climate change, biodiversity loss, land degradation, desertification and the emergence of zoonotic diseases ("halting deforestation and maintaining forests", also "halting deforestation"); (2) restoring degraded forests and landscapes and putting more trees into agricultural settings as cost-effective means for improving natural assets and generating economic, social and environmental benefits ("restoring degraded lands and expanding agroforestry", also "restoration"); and (3) increasing sustainable forest use and building green value chains to help meet future demand for materials and ecosystem services and support greener and circular economies, particularly at the local level ("sustainably using forests and building green value chains", also "sustainable use").

Green. Used in this report (e.g. green value chains, green jobs, green economy) to refer to approaches involving the pursuit of knowledge, technology, innovation and practices with the aim of creating more environmentally friendly and ecologically responsible production systems, producing more with less, minimizing impacts on the environment and sustaining natural resources for current and future generations.

Green jobs. Decent jobs that contribute to conserving or restoring the environment, be they in traditional sectors such as manufacturing and construction or in new, emerging green sectors such as renewable energy and energy efficiency.[571]

Green recovery. The process of revitalizing economies and reversing disruptions to trade and transport caused by the COVID-19 pandemic and associated containment measures by prioritizing investments that reduce the risks presented by climate change, biodiversity loss and other environmental challenges and promote sustainable development. A green recovery would enable countries to build back better, with investments driving economic growth, short-term job creation and significant longer-term economic, social and environmental benefits.

Non-timber forest products. All biological materials other than timber which are extracted from forests for human use.[572] Note that this definition differs from that used in one paper cited in this report, which is as follows: Wild native or non-native biological organisms and materials, other than high-value timber, collected from landscapes and habitats.[573]

Non-wood forest products. Goods of biological origin other than wood, derived from forests, other wooded land and trees outside forests.[574]

Other land with tree cover. Land not classified as forest but which has a tree-canopy cover of at least 10 percent and an area of more than 0.5 ha (e.g. orchards).[2]

Other wooded land. Land not classified as "forest", spanning more than 0.5 hectares; with trees higher than 5 metres and a canopy cover of 5–10 percent, or trees able to reach these thresholds *in situ*; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use.

GLOSSARY

Payment for ecosystem services. A payment made by the beneficiaries or users of an ecosystem service to the providers of that service. In practice, this may take the form of a series of payments in return for receiving a flow of benefits or ecosystem services.

Substitution factor. Typically used to express the emissions that would be avoided if a wood-based product is used instead of a product made from another material providing the same function. Thus, a substitution factor of 1 would mean a reduction of 1 kg of carbon emissions for every 1 kg of wood used in place of non-wood materials. Substitution gains may be counterbalanced by a reduction in forest carbon stock and other leakage effects between regions and need to be further assessed and considered.

Trees outside forests. Trees growing in land uses not categorized as forest (e.g. other wooded land and other land with tree cover).[2]

***Note*:** The definitions provided here are for the convenience of readers and are not necessarily official FAO definitions.

REFERENCES

1 **FAO**. 2020. *Global Forest Resources Assessment 2020 – Main report*. FAO. https://doi.org/10.4060/ca9825en

2 **FAO**. 2018. *Terms and definitions – FRA 2020.* Forest Resources Assessment Working Paper 188. Rome. (also available at https://www.fao.org/3/I8661EN/i8661en.pdf).

3 **FAO**. 2018. *Terms and definitions – FRA 2020.* Forest Resources Assessment Working Paper 188. Rome. (also available at https://www.fao.org/3/I8661EN/i8661en.pdf).

4 **FAO**. 2020. *Global Forest Resources Assessment 2020 – Main report*. FAO. https://doi.org/10.4060/ca9825en

5 **FAO**. In preparation. *Global Forest Resources Assessment – Remote sensing survey.*

6 **FAO**. 2020. *Global Forest Resources Assessment 2020 – Main report*. FAO. https://doi.org/10.4060/ca9825en

7 **BGCI**. 2021. *State of the World's Trees*. Richmond, UK, Botanic Gardens Conservation International (BGCI).

8 **Vié, J.-C., Hilton-Taylor, C. & Stuart, S.N.** 2009. *Wildlife in a changing world – An analysis of the 2008 IUCN Red List of Threatened Species*. International Union for Conservation of Nature (IUCN). 184 pp.

9 **Burley, J.** 2002. Forest biological diversity: an overview. *Unasylva*, 209: 3–9.

10 **FAO.** 2014. *The State of the World's Forest Genetic Resources*. Rome, Commission on Genetic Resources for Food and Agriculture and FAO. 276 p.

11 **De Vos, J.M., Joppa, L.N., Gittleman, J.L., Stephens, P.R. & Pimm, S.L.** 2015. Estimating the normal background rate of species extinction: background rate of extinction. *Conservation Biology*, 29(2): 452–462. https://doi.org/10.1111/cobi.12380

12 **FAO**. 2021. *The State of the World's Land and Water Resources for Food and Agriculture – Systems at breaking point*. Rome, FAO. 80 p. https://doi.org/10.4060/cb7654en

13 **FAO**. 2021. *The State of the World's Land and Water Resources for Food and Agriculture – Systems at breaking point*. Rome, FAO. https://doi.org/10.4060/cb7654en

14 **Pye, J.M., Holmes, T.P., Prestemon, J.P. & Wear, D.N.** 2011. Economic impacts of the southern pine beetle. *In:* R.N. Coulson & K.D. Klepzig, eds. *Southern pine beetle II*, pp. 213–222. Gen. Tech. Rep. SRS-140. Asheville, USA, US Department of Agriculture Forest Service, Southern Research Station. (also available at https://www.srs.fs.usda.gov/pubs/39071).

15 **Hlásny, T., König, L., Krokene, P., Lindner, M., Montagné-Huck, C., Müller, J., Qin, H., *et al.*** 2021. Bark beetle outbreaks in Europe: state of knowledge and ways forward for management. *Current Forestry Reports*, 7(3): 138–165. https://doi.org/10.1007/s40725-021-00142-x.

16 **FAO**. 2020. *Global Forest Resources Assessment 2020 – Main report*. FAO. https://doi.org/10.4060/ca9825en

17 **van Wees, D., van der Werf, G.R., Randerson, J.T., Andela, N., Chen, Y. & Morton, D.C.** 2021. The role of fire in global forest loss dynamics. *Global Change Biology*, 27(11): 2377–2391. https://doi.org/10.1111/gcb.15591

18 **Davey, S.M. & Sarre, A.** 2020. Editorial: the 2019/20 Black Summer bushfires. *Australian Forestry*, 83(2): 47–51. https://doi.org/10.1080/00049158.2020.1769899

19 **FAO**. 2020. *Global Forest Resources Assessment 2020 – Main report*. FAO. https://doi.org/10.4060/ca9825en

20 **FAO**. 2020. *Global Forest Resources Assessment 2020 – Main report*. FAO. https://doi.org/10.4060/ca9825en

21 **FAO**. 2020. *Global Forest Resources Assessment 2020 – Main report*. FAO. https://doi.org/10.4060/ca9825en

22 **Friedlingstein, P., Jones, M.W., O'Sullivan, M., Andrew, R.M., Bakker, D.C.E., Hauck, J., Le Quéré, C. *et al.*** 2021. Global carbon budget 2021. Anthroposphere – energy and emissions. https://doi.org/10.5194/essd-2021-386

23 **Intergovernmental Panel on Climate Change & Edenhofer, O., eds.** 2014. *Climate change 2014: mitigation of climate change – Working Group III contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. New York, NY, Cambridge University Press. 1435 pp.

24 **Friedlingstein, P., Jones, M.W., O'Sullivan, M., Andrew, R.M., Bakker, D.C.E., Hauck, J., Le Quéré, C. *et al.*** 2021. Global carbon budget 2021. Anthroposphere – energy and emissions. https://doi.org/10.5194/essd-2021-386

REFERENCES

25 **Harris, N.L., Gibbs, D.A., Baccini, A., Birdsey, R.A., de Bruin, S., Farina, M., Fatoyinbo, L. *et al.*** 2021. Global maps of twenty-first century forest carbon fluxes. *Nature Climate Change*, 11(3): 234–240. https://doi.org/10.1038/s41558-020-00976-6

26 **Leite-Filho, A.T., Soares-Filho, B.S., Davis, J.L., Abrahão, G.M. & Börner, J.** 2021. Deforestation reduces rainfall and agricultural revenues in the Brazilian Amazon. *Nature Communications*, 12(1): 2591. https://doi.org/10.1038/s41467-021-22840-7

27 **Duku, C. & Hein, L.** 2021. The impact of deforestation on rainfall in Africa: a data-driven assessment. *Environmental Research Letters*, 16(6): 064044. https://doi.org/10.1088/1748-9326/abfcfb

28 **Schwaab, J., Meier, R., Mussetti, G., Seneviratne, S., Bürgi, C. & Davin, E.L.** 2021. The role of urban trees in reducing land surface temperatures in European cities. *Nature Communications*, 12(1): 6763. https://doi.org/10.1038/s41467-021-26768-w

29 **Jones, K.E., Patel, N.G., Levy, M.A., Storeygard, A., Balk, D., Gittleman, J.L. & Daszak, P.** 2008. Global trends in emerging infectious diseases. *Nature*, 451(7181): 990–993. https://doi.org/10.1038/nature06536

30 **Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services**. 2020. *Workshop report on biodiversity and pandemics of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES).* Zenodo. https://doi.org/10.5281/ZENODO.4147317

31 **Riesco, I.L.** 2006. *Forest loss and human health: focus on EU policies and practices*. FERN.

32 **Venkatesh, S.** 2020. Coming out of the jungle, infectious diseases. In: *Down to Earth* [online]. [Cited 8 November 2021]. https://www.downtoearth.org.in/news/forests/coming-out-of-the-jungle-infectious-diseases-70969

33 **Wilcox, B.A. & Ellis, B.R.** 2006. Forests and emerging infectious diseases of humans. *Unasylva*, 224: 11–18. (also available at https://www.fao.org/3/a0789e/a0789e03.htm).

34 **Olivero, J., Fa, J.E., Real, R., Márquez, A.L., Farfán, M.A., Vargas, J.M., Gaveau, D. *et al.*** 2017. Recent loss of closed forests is associated with Ebola virus disease outbreaks. *Scientific Reports*, 7(1): 14291. https://doi.org/10.1038/s41598-017-14727-9

35 **Rulli, M.C., Santini, M., Hayman, D.T.S. & D'Odorico, P.** 2017. The nexus between forest fragmentation in Africa and Ebola virus disease outbreaks. *Scientific Reports*, 7(1): 41613. https://doi.org/10.1038/srep41613

36 **Newton, P., Castle, S.E., Kinzer, A.T., Miller, D.C., Oldekop, J.A., Linhares-Juvenal, T., Pina, L., Madrid, M. & de Lamo, J.** 2022. *The number of forest- and tree-proximate people – A new methodology and global estimates*. Rome, FAO.

37 **Castañeda, A., Doan, D., Newhouse, D., Nguyen, M.C., Uematsu, H. & Azevedo, J.P.** 2018. A new profile of the global poor. *World Development*, 101: 250–267. https://doi.org/10.1016/j.worlddev.2017.08.002

38 **Miller, D.C., Muñoz-Mora, J.C. & Christiaensen, L.** 2017. Prevalence, economic contribution, and determinants of trees on farms across Sub-Saharan Africa. *Forest Policy and Economics*, 84: 47–61. https://doi.org/10.1016/j.forpol.2016.12.005

39 **FAO**. 2020. *Global Forest Resources Assessment 2020 – Main report*. FAO. https://doi.org/10.4060/ca9825en

40 **FAO**. 2020. *Global Forest Resources Assessment 2020 – Main report*. FAO. https://doi.org/10.4060/ca9825en

41 **FAO**. 2020. *Global Forest Resources Assessment 2020 – Main report*. FAO. https://doi.org/10.4060/ca9825en

42 **FAO**. 2020. *Global Forest Resources Assessment 2020 – Main report*. FAO. https://doi.org/10.4060/ca9825en

43 **Rights and Resources Initiative**. 2018. *At a crossroads – Consequential trends in recognition of community-based forest tenure from 2002–2017.* Rights and Resources Initiative. https://doi.org/10.53892/UCYL3747

44 **Miller, D.C., Rana, P., Nakamura, K., Irwin, S., Cheng, S.H., Ahlroth, S. & Perge, E.** 2021. A global review of the impact of forest property rights interventions on poverty. *Global Environmental Change*, 66: 102218. https://doi.org/10.1016/j.gloenvcha.2020.102218

45 **Meinzen-Dick, R.** 2009. *Property rights for poverty reduction?* 10 p. UN/DESA Working Papers 91. New York, USA, UN Department of Economic and Social Affairs.

46 **Hajjar, R., Newton, P., Ihalainen, M., Agrawal, A. & Gabay, M.** 2020. Levers for alleviating poverty in forests and tree-based systems. *Forests, trees and the eradication of poverty – Potential and limitations*, pp. 125–176. IUFRO World Series 39. International Union of Forest Research Organizations.

47 **World Bank**. 2021. *The Changing Wealth of Nations 2021 – Managing assets for the future*. Washington, DC.

48 **World Bank**. 2021. *The Changing Wealth of Nations 2021 – Managing assets for the future*. Washington, DC.

49 **World Bank**. 2021. *The Changing Wealth of Nations 2021 – Managing assets for the future*. Washington, DC.

50 **World Economic Forum**. 2020. *Nature risk rising – Why the crisis engulfing nature matters for business and the economy*. New Nature Economy. (also available at https://www3.weforum.org/docs/WEF_New_Nature_Economy_Report_2020.pdf).

51 **Foundation for Sustainable Development**. Undated. *ESVD* [online]. [Cited 18 January 2022]. www.esvd.info

52 **Sorrenti, S.** 2017. *Non-wood forest products in international statistical systems*. Rome, FAO.

53 **Brander, L.M., de Groot, R., Schägner, P., Guisado-Goñi, V., van 't Hoff, V. & Solomonides, S.** 2022. *The role of forest ecosystem services to support the green recovery – Evidence from the Ecosystem Services Valuation Database*. Background paper for State of the World's Forests 2022. FAO.

54 **Brander, L.M., de Groot, R., Schägner, P., Guisado-Goñi, V., van 't Hoff, V. & Solomonides, S.** 2022. *The role of forest ecosystem services to support the green recovery – Evidence from the Ecosystem Services Valuation Database.* Background paper for State of the World's Forests 2022. FAO.

55 **Balmford, A., Green, J.M.H., Anderson, M., Beresford, J., Huang, C., Naidoo, R., Walpole, M. *et al.*** 2015. Walk on the wild side: estimating the global magnitude of visits to protected areas. *PLOS Biology*, 13(2): e1002074. https://doi.org/10.1371/journal.pbio.1002074

56 **Li, Y., Mei, B., Linhares-Juvenal, T. & Formenton Cardoso, N.** 2022. *Forest sector contributions to the national economies in 2015 – The direct, indirect and induced effects on value-added, employment and labour income*, Rome, FAO.

57 **Li, Y., Mei, B., Linhares-Juvenal, T. & Formenton Cardoso, N.** 2022. *Forest sector contributions to the national economies in 2015 – The direct, indirect and induced effects on value-added, employment and labour income*, Rome, FAO.

58 **Li, Y., Mei, B., Linhares-Juvenal, T. & Formenton Cardoso, N.** 2022. *Forest sector contributions to the national economies in 2015 – The direct, indirect and induced effects on value-added, employment and labour income.* Rome, FAO.

59 **Li, Y., Mei, B., Linhares-Juvenal, T. & Formenton Cardoso, N.** 2022. *Forest sector contributions to the national economies in 2015 – The direct, indirect and induced effects on value-added, employment and labour income*, Rome, FAO.

60 **FAO**. Undated. *FAOSTAT* [online]. [Cited 27 December 2021]. https://www.fao.org/faostat/en/#data/FO

61 **Lippe, R.S., Cui, S. & Schweinle, J.** Forthcoming. *Contribution of the forest sector to total employment in national economies*. FAO.

62 **Lippe, R.S., Cui, S. & Schweinle, J.** Forthcoming. *Contribution of the forest sector to total employment in national economies*. FAO.

63 **International Monetary Fund**. 2021. *World economic outlook update*. January. 11 p.

64 **Lakner, C., Yonzan, N., Mahler, D.G., Castaneda Aguilar, A. & Wu, H.** 2021. Updated estimates of the impact of COVID-19 on global poverty: looking back at 2020 and the outlook for 2021. In: *World Bank Blogs* [online]. [Cited 30 December 2021]. https://blogs.worldbank.org/opendata/updated-estimates-impact-covid-19-global-poverty-looking-back-2020-and-outlook-2021

65 **Wunder, S., Kaimowitz, D., Jensen, S. & Feder, S.** 2021. Coronavirus, macroeconomy, and forests: what likely impacts? *Forest Policy and Economics*, 131: 102536. https://doi.org/10.1016/j.forpol.2021.102536

66 **UN**. Undated. *UN Comtrade | International Trade Statistics Database* [online]. [Cited 13 November 2021]. https://comtrade.un.org/

67 **International Trade Centre**. Undated. *Trade map – Trade statistics for international business development* [online]. [Cited 4 January 2022]. https://www.trademap.org/Index.aspx

REFERENCES

68 **Held, C., Meier-Landsberg, E. & Alonso, V.** 2022. *Global forest sector outlook 2050 – Assessing future demand and sources of timber for a sustainable economy.* Background paper for the State of the World's Forests 2022. FAO.

69 **Held, C., Meier-Landsberg, E. & Alonso, V.** 2022. *Global forest sector outlook 2050 – Assessing future demand and sources of timber for a sustainable economy.* Background paper for the State of the World's Forests 2022. FAO.

70 **Shupler, M., Mwitari, J., Gohole, A., Anderson de Cuevas, R., Puzzolo, E., Čukić, I., Nix, E. *et al.*** 2021. COVID-19 impacts on household energy & food security in a Kenyan informal settlement: the need for integrated approaches to the SDGs. *Renewable and Sustainable Energy Reviews*, 144: 111018. https://doi.org/10.1016/j.rser.2021.111018

71 **Stoner, O., Lewis, J., Martínez, I.L., Gumy, S., Economou, T. & Adair-Rohani, H.** 2021. Household cooking fuel estimates at global and country level for 1990 to 2030. *Nature Communications*, 12(1): 5793. https://doi.org/10.1038/s41467-021-26036-x

72 **Lim, S.S., Vos, T., Flaxman, A.D., Danaei, G., Shibuya, K., Adair-Rohani, H., AlMazroa, M.A. *et al.*** 2012. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *The Lancet*, 380(9859): 2224–2260. https://doi.org/10.1016/S0140-6736(12)61766-8

73 **Bennitt, F.B., Wozniak, S.S., Causey, K., Burkart, K. & Brauer, M.** 2021. Estimating disease burden attributable to household air pollution: new methods within the Global Burden of Disease Study. *The Lancet Global Health*, 9: S18. https://doi.org/10.1016/S2214-109X(21)00126-1

74 **Chidumayo, E.N. & Gumbo, D.J.** 2013. The environmental impacts of charcoal production in tropical ecosystems of the world: a synthesis. *Energy for Sustainable Development*, 17(2): 86–94. https://doi.org/10.1016/j.esd.2012.07.004

75 **IEA, IRENA, UN, World Bank and WHO**. 2021. *Tracking SDG7 – The Energy Progress Report 2021*. Washington, DC, World Bank.

76 **Stoner, O., Lewis, J., Martínez, I.L., Gumy, S., Economou, T. & Adair-Rohani, H.** 2021. Household cooking fuel estimates at global and country level for 1990 to 2030. *Nature Communications*, 12(1): 5793. https://doi.org/10.1038/s41467-021-26036-x

77 **FAO**. Undated. *FAOSTAT* [online]. [Cited 11 January 2022]. https://www.fao.org/faostat/en/#data/FO

78 **FAO**. 2014. *State of the World's Forests 2014 – Enhancing the socioeconomic benefits from forests*. Rome, FAO. 119 p.

79 **Shackleton, C.M. & de Vos, A.** 2022. How many people globally actually use non-timber forest products? *Forest Policy and Economics*, 135: 102659. https://doi.org/10.1016/j.forpol.2021.102659

80 **Lovrić, M., Da Re, R., Vidale, E., Prokofieva, I., Wong, J., Pettenella, D., Verkerk, P.J. *et al.*** 2020. Non-wood forest products in Europe – a quantitative overview. *Forest Policy and Economics*, 116: 102175. https://doi.org/10.1016/j.forpol.2020.102175

81 **FAO**. Undated. *FAOSTAT* [online]. [Cited 27 December 2021]. https://www.fao.org/faostat/en/#data/FO

82 **Jenkins, M., Timoshyna, A. & Cornthwaite, M.** 2018. *Wild at home – Exploring the global harvest, trade and use of wild plant ingredients*. Cambridge, United Kingdom, TRAFFIC International.

83 **Nasi, R., Taber, A. & Van Vliet, N.** 2011. Empty forests, empty stomachs? Bushmeat and livelihoods in the Congo and Amazon Basins. *International Forestry Review*, 13(3): 355–368. https://doi.org/10.1505/146554811798293872

84 **Coad, L., Fa, J.E., Abernethy, K., Van Vliet, N., Santamaria, C., Wilkie, D., El Bizri, H.R. *et al.*** 2019. *Towards a sustainable, participatory and inclusive wild meat sector.* Center for International Forestry Research (CIFOR). https://doi.org/10.17528/cifor/007046

85 **Señaris and Ferrer (2012), as seen in**: **Coad, L., Fa, J.E., Abernethy, K., Van Vliet, N., Santamaria, C., Wilkie, D., El Bizri, H.R. *et al.*** 2019. *Towards a sustainable, participatory and inclusive wild meat sector.* Center for International Forestry Research (CIFOR). https://doi.org/10.17528/cifor/007046

86 **Jagger, P. & Cheek, J.Z.** 2020. Key concepts for understanding forest-poverty dynamics. *In*: D.C. Miller, S. Mansourian & C. Wildburger, eds. *Forests, trees and the eradication of poverty – Potential and limitations*, pp. 33–54. IUFRO World Series. Vienna, International Union of Forest Research Organizations (IUFRO).

87 **Angelsen, A., Martius, C., de Sy, V. & Duchelle, A.** 2018. *Transforming REDD+ – Lessons and new directions*. Bogor, Indonesia, Center for International Forestry Research. 276 pp.

88 **Hickey, G.M., Pouliot, M., Smith-Hall, C., Wunder, S. & Nielsen, M.R.** 2016. Quantifying the economic contribution of wild food harvests to rural livelihoods: a global-comparative analysis. *Food Policy*, 62: 122–132. https://doi.org/10.1016/j.foodpol.2016.06.001

89 **Chaudhury, G., Basumatari, M., Darji, C.B., Ahmed, A.F., Borah, D., Sah, R.K., Devi, A. *et al.*** 2021. Economic significance of wild bioresources to rural communities in the Eastern Himalayan state of Assam, Northeast India. *Trees, Forests and People*, 5: 100102. https://doi.org/10.1016/j.tfp.2021.100102

90 **Laird, S.A., Awung, G.L., Lysinge, R.J. & Ndive, L.E.** 2011. The interweave of people and place: biocultural diversity in migrant and indigenous livelihoods around Mount Cameroon. *International Forestry Review*, 13(3): 275–293. https://doi.org/10.1505/146554811798293890

91 **Asselin, H.** 2015. Indigenous forest knowledge. *In*: K. Peh, R. Corlett & Y. Bergeron, eds. *Routledge handbook of forest ecology*, pp. 586–596. Routledge.

92 **Noack, F., Riekhof, M.-C. & Di Falco, S.** 2019. Droughts, biodiversity, and rural incomes in the tropics. *Journal of the Association of Environmental and Resource Economists*, 6(4): 823–852. https://doi.org/10.1086/703487

93 **Bawa, A. & Atengdem, P.B.** 2016. Impact of CLIP project on the livelihood outcomes of sheabutter processing women in Karaga district of Northern Region, Ghana. *International Journal for Research in Agricultural and Food Science*, 2(4): 07–29. (also available at https://gnpublication.org/index.php/afs/article/view/359).

94 **Laube, W.** 2015. Global shea nut commodity chains and poverty eradication in northern Ghana: myth or reality? *UDS International Journal of Development*, 2(1): 128–147. (also available at http://udsspace.uds.edu.gh:80/handle/123456789/456).

95 **Mohammed, F., Boateng, S. & Al-hassan, S.** 2013. Effects of adoption of improved sheabutter processing technology on women's livelihoods and their microenterprise growth. *American Journal of Humanities and Social Sciences*, 1(4): 244–250. https://doi.org/10.11634/232907811301419

96 **FAO, Center for International Forestry Research, International Forestry Resources and Institutions Research Network & World Bank**. 2016. *National socioeconomic surveys in forestry – Guidance and survey modules for measuring the multiple roles of forests in household welfare and livelihoods*. FAO Forestry Paper 179. Rome.

97 **Curtis, P.G., Slay, C.M., Harris, N.L., Tyukavina, A. & Hansen, M.C.** 2018. Classifying drivers of global forest loss. *Science*, 361(6407): 1108–1111. https://doi.org/10.1126/science.aau3445

98 **De Sy, V., Herold, M., Brockhaus, M., Di Gregorio, M. & Ochieng, R.** 2018. Information and policy change: data on drivers can drive change if used wisely. *Transforming REDD+: Lessons and New Directions*, Bogor, Indonesia, Center for International Forestry Research.

99 **Hosonuma, N., Herold, M., Sy, V.D., Fries, R.S.D., Brockhaus, M., Verchot, L., Angelsen, A. *et al.*** 2012. An assessment of deforestation and forest degradation drivers in developing countries. *Environmental Research Letters*, 7(4): 044009. https://doi.org/10.1088/1748-9326/7/4/044009

100 **Pendrill, F., Persson, U.M., Godar, J. & Kastner, T.** 2019. Deforestation displaced: trade in forest-risk commodities and the prospects for a global forest transition. *Environmental Research Letters*, 14(5): 055003. https://doi.org/10.1088/1748-9326/ab0d41

101 **FAO**. In preparation. *Global Forest Resources Assessment – Remote sensing survey.*

102 **FAO**. In preparation. *Global Forest Resources Assessment – Remote sensing survey.*

103 **Dummett, C. & Blundell, A.** 2021. *Illicit harvest, complicit goods – The state of illegal deforestation for agriculture*. 81 p. Forest Trends.

104 **Pacheco, P., Mo, K., Dudley, N., Shapiro, A., Aguilar-Amuchastegui, N., Ling, P.-Y., Anderson, C. *et al.*** 2021. *Deforestation fronts – Drivers and responses in a changing world*. Gland, Switzerland, World Wide Fund for Nature.

105 **UN**. 2019. *World Population Prospects 2019 – Highlights*. United Nations. (also available at https://doi.org/10.18356/13bf5476-en).

REFERENCES

106 **van Dijk, M., Morley, T., Rau, M.L. & Saghai, Y.** 2021. A meta-analysis of projected global food demand and population at risk of hunger for the period 2010–2050. *Nature Food*, 2(7): 494–501. https://doi.org/10.1038/s43016-021-00322-9

107 **Meyfroidt, P., Lambin, E.F., Erb, K.-H. & Hertel, T.W.** 2013. Globalization of land use: distant drivers of land change and geographic displacement of land use. *Current Opinion in Environmental Sustainability*, 5(5): 438–444. https://doi.org/10.1016/j.cosust.2013.04.003

108 **Hoang, N.T. & Kanemoto, K.** 2021. Mapping the deforestation footprint of nations reveals growing threat to tropical forests. *Nature Ecology & Evolution*, 5(6): 845–853. https://doi.org/10.1038/s41559-021-01417-z

109 **FAO**. In preparation. *Global Forest Resources Assessment – Remote sensing survey.*

110 **Voora, V., Larrea, C., Bermudez, S. & Baliño, S.** 2020. *Global market report – Palm oil*. International Institute for Sustainable Development and State of Sustainability Initiatives. 16 p.

111 **Franklin, S.L. & Pindyck, R.S.** 2018. Tropical forests, tipping points, and the social cost of deforestation. *Ecological Economics*, 153: 161–171. https://doi.org/10.1016/j.ecolecon.2018.06.003

112 **Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S.L., Péan, C., Berger, S., Caud, N. *et al.*, eds.** 2021. *Climate Change 2021 – The physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

113 **UN Environment Programme & International Union for Conservation of Nature**. 2021. *Nature-based solutions for climate change mitigation*. Nairobi, Kenya and Gland, Switzerland. 35 p. (also available at https://wedocs.unep.org/xmlui/bitstream/handle/20.500.11822/37318/NBSCCM.pdf).

114 **Intergovernmental Panel on Climate Change**. 2019. *Climate change and land – An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, *et al.*, eds.

115 **Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S.L., Péan, C., Berger, S., Caud, N. *et al.*, eds.** 2021. *Climate Change 2021 – The physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

116 **Intergovernmental Panel on Climate Change**. 2019. *Climate Change and Land – An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, *et al.*, eds

117 **Goldstein, A., Turner, W.R., Spawn, S.A., Anderson-Teixeira, K.J., Cook-Patton, S., Fargione, J., Gibbs, H.K. *et al.*** 2020. Protecting irrecoverable carbon in Earth's ecosystems. *Nature Climate Change*, 10(4): 287–295. https://doi.org/10.1038/s41558-020-0738-8

118 **Busch, J. & Engelmann, J.** 2017. Cost-effectiveness of reducing emissions from tropical deforestation, 2016–2050. *Environmental Research Letters*, 13(1): 015001. https://doi.org/10.1088/1748-9326/aa907c

119 **Roe, S., Streck, C., Beach, R., Busch, J., Chapman, M., Daioglou, V., Deppermann, A. *et al.*** 2021. Land-based measures to mitigate climate change: potential and feasibility by country. *Global Change Biology*, 27(23): 6025–6058. https://doi.org/10.1111/gcb.15873

120 **Austin, K.G., Baker, J.S., Sohngen, B.L., Wade, C.M., Daigneault, A., Ohrel, S.B., Ragnauth, S. *et al.*** 2020. The economic costs of planting, preserving, and managing the world's forests to mitigate climate change. *Nature Communications*, 11(1): 5946. https://doi.org/10.1038/s41467-020-19578-z

121 **Roe, S., Streck, C., Beach, R., Busch, J., Chapman, M., Daioglou, V., Deppermann, A. *et al.*** 2021. Land-based measures to mitigate climate change: potential and feasibility by country. *Global Change Biology*, 27(23): 6025–6058. https://doi.org/10.1111/gcb.15873

122 **Fuss, S., Golub, A. & Lubowski, R.** 2021. The economic value of tropical forests in meeting global climate stabilization goals. *Global Sustainability*, 4: e1. https://doi.org/10.1017/sus.2020.34

123 **FAO**. 2019. *The State of the World's Biodiversity for Food and Agriculture,* J. Bélanger & D. Pilling (eds.). FAO Commission on Genetic Resources for Food and Agriculture Assessments. Rome.

124 **Klein, A.-M., Vaissière, B.E., Cane, J.H., Steffan-Dewenter, I., Cunningham, S.A., Kremen, C. & Tscharntke, T.** 2007. Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences*, 274(1608): 303–313. https://doi.org/10.1098/rspb.2006.3721

125 **Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Service**. 2019. *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Zenodo. https://doi.org/10.5281/ZENODO.3831673

126 **Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R.T., Molnár, Z., Hill, R. *et al.*** 2018. Assessing nature's contributions to people. *Science*, 359(6373): 270–272. https://doi.org/10.1126/science.aap8826

127 **Hill, S.L.L., Arnell, A., Maney, C., Butchart, S.H.M., Hilton-Taylor, C., Ciciarelli, C., Davis, C. *et al.*** 2019. Measuring forest biodiversity status and changes globally. *Frontiers in Forests and Global Change*, 2: 70. https://doi.org/10.3389/ffgc.2019.00070

128 **Waldron, A., Adams, V., Allan, J., Arnell, A., Abrantes, J.P., Asner, G., Atkinson, S. *et al.*** 2020. *Protecting 30 percent of the planet – Costs, benefits and economic implications*. Working paper analysing the economic implications of the proposed 30% target for areal protection in the draft post-2020 Global Biodiversity Framework. https://doi.org/10.13140/RG.2.2.19950.64327

129 **Zomer, R.J., Trabucco A, Coe, R., Place, F., van Noordwijk, M. & Xu, J.C.** 2014. *Trees on farms – An update and reanalysis of agroforestry's global extent and socio-ecological characteristics*. World Agroforestry Centre (ICRAF). https://doi.org/10.5716/WP14064.PDF

130 **World Resources Institute**. undated. *Global Forest Watch* [online]. [Cited 14 November 2021]. https://www.wri.org/initiatives/global-forest-watch

131 **Millennium Ecosystem Assessment (Program), ed.** 2005. *Ecosystems and human well-being – Synthesis*. Washington, DC, Island Press. 137 p.

132 **Dasgupta, P.** 2021. *The economics of biodiversity: the Dasgupta review – Full report*. Updated: 18 February 2021 edition. London, HM Treasury. 610 p.

133 **WWAP (UN World Water Assessment Programme)/UN-Water**. 2018. *World Water Development Report 2018*. In: *UN-Water* [online]. [Cited 8 November 2021]. https://www.unwater.org/publications/world-water-development-report-2018/

134 **UNESCO World Water Assessment Programme**. 2021. *United Nations World Water Development Report 2021 – Valuing water.* UN Educational, Scientific and Educational Organization.

135 **Singh, S. & Mishra, A.** 2014. Deforestation-induced costs on the drinking water supplies of the Mumbai metropolitan, India. *Global Environmental Change*, 27: 73–83. https://doi.org/10.1016/j.gloenvcha.2014.04.020

136 **Turpie, J., Warr, B. & Carter Ingram, J.** 2015. *Benefits of forest ecosystems in Zambia and the role of REDD+ in a green economy transformation.* (also available at https://www.globallandscapesforum.org/publication/benefits-of-forest-ecosystems-in-zambia-and-the-role-of-redd-in-a-green-economy-transformation/).

137 **Arias, M.E., Cochrane, T.A., Lawrence, K.S., Killeen, T.J. & Farrell, T.A.** 2011. Paying the forest for electricity: a modelling framework to market forest conservation as payment for ecosystem services benefiting hydropower generation. *Environmental Conservation*, 38(4): 473–484. https://doi.org/10.1017/S0376892911000464

138 **Moran, E.F., Lopez, M.C., Moore, N., Müller, N. & Hyndman, D.W.** 2018. Sustainable hydropower in the 21st century. *Proceedings of the National Academy of Sciences*, 115(47): 11891–11898. https://doi.org/10.1073/pnas.1809426115

139 **Annandale, G.W., Morris, G.L. & Karki, P.** 2016. *Extending the life of reservoirs – Sustainable sediment management for dams and run-of-river hydropower.* Washington, DC, World Bank. https://doi.org/10.1596/978-1-4648-0838-8

140 **Menéndez, P., Losada, I.J., Torres-Ortega, S., Narayan, S. & Beck, M.W.** 2020. The global flood protection benefits of mangroves. *Scientific Reports*, 10(1): 4404. https://doi.org/10.1038/s41598-020-61136-6

REFERENCES

141 **Menéndez, P., Losada, I.J., Torres-Ortega, S., Narayan, S. & Beck, M.W.** 2020. The global flood protection benefits of mangroves. *Scientific Reports*, 10(1): 4404. https://doi.org/10.1038/s41598-020-61136-6

142 **Allen, T., Murray, K.A., Zambrana-Torrelio, C., Morse, S.S., Rondinini, C., Di Marco, M., Breit, N. *et al.*** 2017. Global hotspots and correlates of emerging zoonotic diseases. *Nature Communications*, 8(1): 1124. https://doi.org/10.1038/s41467-017-00923-8

143 **Wilcox, B.A. & Ellis, B.R.** 2006. Forests and emerging infectious diseases of humans. *Unasylva*, 57: 11–18. (also available at https://www.fao.org/3/a0789e/a0789e03.htm).

144 **Sow, A., Nikolay, B., Faye, O., Cauchemez, S., Cano, J., Diallo, M., Faye, O. *et al.*** 2020. Changes in the transmission dynamic of *Chikungunya* virus in southeastern Senegal. *Viruses*, 12(2): 196. https://doi.org/10.3390/v12020196

145 **Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services**. 2020. Workshop Report on Biodiversity and Pandemics of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). Zenodo. https://doi.org/10.5281/ZENODO.4147317

146 **Dobson, A.P., Pimm, S.L., Hannah, L., Kaufman, L., Ahumada, J.A., Ando, A.W., Bernstein, A. *et al.*** 2020. Ecology and economics for pandemic prevention. *Science*, 369(6502): 379–381. https://doi.org/10.1126/science.abc3189

147 **Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services**. 2020. Workshop Report on Biodiversity and Pandemics of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). Zenodo. https://doi.org/10.5281/ZENODO.4147317

148 **FAO**. 2020. *FAO COVID-19 Response and Recovery Programme – Preventing the next zoonotic pandemic*. FAO. https://doi.org/10.4060/cb0301en

149 **Jung, M., Arnell, A., de Lamo, X., García-Rangel, S., Lewis, M., Mark, J., Merow, C. *et al.*** 2021. Areas of global importance for conserving terrestrial biodiversity, carbon and water. *Nature Ecology & Evolution*, 5(11): 1499–1509. https://doi.org/10.1038/s41559-021-01528-7

150 **Reed, J., Barlow, J., Carmenta, R., van Vianen, J. & Sunderland, T.** 2019. Engaging multiple stakeholders to reconcile climate, conservation and development objectives in tropical landscapes. *Biological Conservation*, 238: 108229. https://doi.org/10.1016/j.biocon.2019.108229

151 **Denier, L., Scherr, S., Shames, S., Chatterton, P., Hovani, L. & Stam, N.** 2015. *The little sustainable landscapes book*. Oxford, UK, Global Canopy Foundation. (also available at https://globalcanopy.org/wp-content/uploads/2021/01/GCP_LSLB_EN.pdf).

152 **Reed, J., Ickowitz, A., Chervier, C., Djoudi, H., Moombe, K., Ros-Tonen, M., Yanou, M. *et al.*** 2020. Integrated landscape approaches in the tropics: a brief stock-take. *Land Use Policy*, 99: 104822. https://doi.org/10.1016/j.landusepol.2020.104822

153 **Intergovernmental Panel on Climate Change**. 2022. *Climate Change 2022 – Impacts, adaptation, and vulnerability*. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. H.O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem & B. Rama, eds. Cambridge University Press. In press.

154 **Meybeck, A., Gitz, V., Wolf, J. & Wong, T.** 2020. *Addressing forestry and agroforestry in National Adaptation Plans – Supplementary guidelines*. Rome/Bogor, Indonesia, FAO and FTA. https://doi.org/10.4060/cb1203en

155 **FAO, ed.** 2017. *The future of food and agriculture – Trends and challenges*. Rome. 163 p.

156 **World Bank**. Undated. *Agricultural land (sq. km)* | *Data* [online]. [Cited 11 November 2021]. https://data.worldbank.org/indicator/AG.LND.AGRI.K2?end=2015&start=1961

157 **Ritchie, H. & Roser, M.** 2013. *Crop yields – Our world in data* [online]. [Cited 8 November 2021]. https://ourworldindata.org/crop-yields#citation

158 **Campanhola, C. & Pandey, S., eds.** 2019. *Sustainable food and agriculture*. Elsevier. https://doi.org/10.1016/C2016-0-01212-3

159 **Byerlee, D., Stevenson, J. & Villoria, N.** 2014. Does intensification slow crop land expansion or encourage deforestation? *Global Food Security*, 3(2): 92–98. https://doi.org/10.1016/j.gfs.2014.04.001

160 **Ritchie, H. & Roser, M.** 2013. *Crop Yields - Our World in Data* [online]. [Cited 8 November 2021]. https://ourworldindata.org/crop-yields#citation

161 **Evenson, R.E. & Rosegrant, M.** 2003. The economic consequences of crop genetic improvement programmes. *In*: R.E. Evenson & D. Gollin, eds. *Crop variety improvement and its effect on productivity – The impact of international agricultural research*, pp. 473–497. Wallingford, CABI. https://doi.org/10.1079/9780851995496.0473

162 **Stevenson, J.R., Villoria, N., Byerlee, D., Kelley, T. & Maredia, M.** 2013. Green Revolution research saved an estimated 18 to 27 million hectares from being brought into agricultural production. *Proceedings of the National Academy of Sciences*, 110(21): 8363–8368. https://doi.org/10.1073/pnas.1208065110

163 **Mosnier, A., Mant, R., Pirker, J., Makoudjou, A., Awono, E., Bodin, P., Tonga, P. *et al.*** 2015. *Modelling land use changes in Cameroon 2000–2030 – A report by the REDD-PAC project.* Cambridge, Laxenburg, Yaoundé, UNEP-WCMC, IIASA, COMIFAC. (also available at http://pure.iiasa.ac.at/id/eprint/13771/).

164 **Mosnier, P., Mant, R., Pirker, J., Bodin, P., Bokelo, D., Tonga, P., Havlik, P. *et al.*** 2015. *Modelling land use changes in the Democratic Republic of Congo 2000-2030. A report by the REDD-PAC project.* (also available at http://pure.iiasa.ac.at/id/eprint/13775/).

165 **Havlík, P., Valin, H., Mosnier, A., Obersteiner, M., Baker, J.S., Herrero, M., Rufino, M.C. *et al.*** 2013. Crop productivity and the global livestock sector: implications for land use change and greenhouse gas emissions. *American Journal of Agricultural Economics*, 95(2): 442–448. https://doi.org/10.1093/ajae/aas085

166 **Lobell, D.B., Baldos, U.L.C. & Hertel, T.W.** 2013. Climate adaptation as mitigation: the case of agricultural investments. *Environmental Research Letters*, 8(1): 015012. https://doi.org/10.1088/1748-9326/8/1/015012

167 **Stabile, M.C.C., Guimarães, A.L., Silva, D.S., Ribeiro, V., Macedo, M.N., Coe, M.T., Pinto, E. *et al.*** 2020. Solving Brazil's land use puzzle: increasing production and slowing Amazon deforestation. *Land Use Policy*, 91: 104362. https://doi.org/10.1016/j.landusepol.2019.104362

168 **Mullan, K., Caviglia-Harris, J.L. & Sills, E.O.** 2021. Sustainability of agricultural production following deforestation in the tropics: evidence on the value of newly-deforested, long-deforested and forested land in the Brazilian Amazon. *Land Use Policy*, 108: 105660. https://doi.org/10.1016/j.landusepol.2021.105660

169 **Garcia, E., Ramos Filho, F., Mallmann, G. & Fonseca, F.** 2017. Costs, benefits and challenges of sustainable livestock intensification in a major deforestation frontier in the Brazilian Amazon. *Sustainability*, 9(1): 158. https://doi.org/10.3390/su9010158

170 **Krause, M., Lotze-Campen, H., Popp, A., Dietrich, J.P. & Bonsch, M.** 2013. Conservation of undisturbed natural forests and economic impacts on agriculture. *Land Use Policy*, 30(1): 344–354. https://doi.org/10.1016/j.landusepol.2012.03.020

171 **Villoria, N.B., Byerlee, D. & Stevenson, J.** 2014. The effects of agricultural technological progress on deforestation: what do we really know? *Applied Economic Perspectives and Policy*, 36(2): 211–237. https://doi.org/10.1093/aepp/ppu005

172 **Byerlee, D., Stevenson, J. & Villoria, N.** 2014. Does intensification slow crop land expansion or encourage deforestation? *Global Food Security*, 3(2): 92–98. https://doi.org/10.1016/j.gfs.2014.04.001

173 **Lobell, D.B., Baldos, U.L.C. & Hertel, T.W.** 2013. Climate adaptation as mitigation: the case of agricultural investments. *Environmental Research Letters*, 8(1): 015012. https://doi.org/10.1088/1748-9326/8/1/015012

174 **Stabile, M.C.C., Guimarães, A.L., Silva, D.S., Ribeiro, V., Macedo, M.N., Coe, M.T., Pinto, E. *et al.*** 2020. Solving Brazil's land use puzzle: increasing production and slowing Amazon deforestation. *Land Use Policy*, 91: 104362. https://doi.org/10.1016/j.landusepol.2019.104362

175 **Garrett, R.D., Levy, S., Carlson, K.M., Gardner, T.A., Godar, J., Clapp, J., Dauvergne, P. *et al.*** 2019. Criteria for effective zero-deforestation commitments. *Global Environmental Change*, 54: 135–147. https://doi.org/10.1016/j.gloenvcha.2018.11.003

176 **Lambin, E.F., Gibbs, H.K., Heilmayr, R., Carlson, K.M., Fleck, L.C., Garrett, R.D., le Polain de Waroux, Y. *et al.*** 2018. The role of supply-chain initiatives in reducing deforestation. *Nature Climate Change*, 8(2): 109–116. https://doi.org/10.1038/s41558-017-0061-1

177 **Rueda, X., Garrett, R.D. & Lambin, E.F.** 2017. Corporate investments in supply chain sustainability: selecting instruments in the agri-food industry. *Journal of Cleaner Production*, 142: 2480–2492. https://doi.org/10.1016/j.jclepro.2016.11.026

REFERENCES

178 **Rothrock, P. & Wheaterer, L.** 2020. *Commitments in action – Corporate tells for financing forest conservation & restoration, 2020* [online]. Forest Trends. [Cited 5 November 2021]. https://www.forest-trends.org/publications/commitments-in-action-corporate-tells-for-financing-forest-conservation-restoration-2020/

179 **Garrett, R.D., Levy, S., Carlson, K.M., Gardner, T.A., Godar, J., Clapp, J., Dauvergne, P. *et al.*** 2019. Criteria for effective zero-deforestation commitments. *Global Environmental Change*, 54: 135–147. https://doi.org/10.1016/j.gloenvcha.2018.11.003

180 **CDP**. 2021. *The collective effort to end deforestation – A pathway for companies to raise their ambition*. (also available at https://www.cdp.net/en/research/global-reports/global-forests-report-2020).

181 **CDP**. 2021. *Home – CDP* [online]. [Cited 10 November 2021]. https://www.cdp.net/en

182 **Burley, H. & Thomson, E.** 2022. *A climate wake-up – But business failing to hear the alarm on deforestation*. Oxford, UK, Global Canopy. (also available at https://forest500.org/sites/default/files/forest500_2022report_final.pdf).

183 **United Nations**. Undated. Action Tracks | United Nations. In: *Food Systems Summit 2021* [online]. [Cited 9 February 2022]. https://www.un.org/en/food-systems-summit/action-tracks

184 **Roberts, C.M., O'Leary, B.C. & Hawkins, J.P.** 2020. Climate change mitigation and nature conservation both require higher protected area targets. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 375(1794): 20190121. https://doi.org/10.1098/rstb.2019.0121

185 **Robinson, B.E., Holland, M.B. & Naughton-Treves, L.** 2014. Does secure land tenure save forests? A meta-analysis of the relationship between land tenure and tropical deforestation. *Global Environmental Change*, 29: 281–293. https://doi.org/10.1016/j.gloenvcha.2013.05.012

186 **FAO**. 2021. *Indigenous Peoples' food systems*. FAO, Alliance of Bioversity International, and CIAT. https://doi.org/10.4060/cb5131en

187 **Lipscomb, M. & Prabakaran, N.** 2020. Property rights and deforestation: evidence from the Terra Legal land reform in the Brazilian Amazon. *World Development*, 129: 104854. https://doi.org/10.1016/j.worlddev.2019.104854

188 **Segura Warnholtz, G., Fernández, M. & Springer, F.** 2017. *Securing forest tenure rights for rural development – Lessons from six countries in Latin America.* (also available at http://hdl.handle.net/10986/26301).

189 **Moffette, F., Alix-Garcia, J., Shea, K. & Pickens, A.H.** 2021. The impact of near-real-time deforestation alerts across the tropics. *Nature Climate Change*, 11(2): 172–178. https://doi.org/10.1038/s41558-020-00956-w

190 **Gibbs, H.K., Munger, J., L'Roe, J., Barreto, P., Pereira, R., Christie, M., Amaral, T. *et al.*** 2016. Did ranchers and slaughterhouses respond to zero-deforestation agreements in the Brazilian Amazon? *Conservation Letters*, 9(1): 32–42. https://doi.org/10.1111/conl.12175

191 **Heilmayr, R., Rausch, L.L., Munger, J. & Gibbs, H.K.** 2020. Brazil's Amazon Soy Moratorium reduced deforestation. *Nature Food*, 1(12): 801–810. https://doi.org/10.1038/s43016-020-00194-5

192 **Carodenuto, S.** 2019. Governance of zero deforestation cocoa in West Africa: new forms of public–private interaction. *Environmental Policy and Governance*, 29(1): 55–66. https://doi.org/10.1002/eet.1841

193 **Silva, de F., Perrin, R.K. & Fulginiti, L.E.** 2019. The opportunity cost of preserving the Brazilian Amazon forest. *Agricultural Economics*, 50(2): 219–227. https://doi.org/10.1111/agec.12478

194 **Jones, K.W., Powlen, K., Roberts, R. & Shinbrot, X.** 2020. Participation in payments for ecosystem services programs in the Global South: a systematic review. *Ecosystem Services*, 45: 101159. https://doi.org/10.1016/j.ecoser.2020.101159

195 **Salzman, J., Bennett, G., Carroll, N., Goldstein, A. & Jenkins, M.** 2018. The global status and trends of payments for ecosystem services. *Nature Sustainability*, 1(3): 136–144. https://doi.org/10.1038/s41893-018-0033-0

196 **Searchinger, T.D., Malins, C., Dumas, P., Baldock, D., Glauber, J., Jayne, T., Huang, J. *et al.*** 2020. *Revising public agricultural support to mitigate climate change*. Washington, DC, World Bank. https://doi.org/10.1596/33677

197 **Searchinger, T.D., Malins, C., Dumas, P., Baldock, D., Glauber, J., Jayne, T., Huang, J. *et al.*** 2020. *Revising public agricultural support to mitigate climate change*. Washington, DC, World Bank. https://doi.org/10.1596/33677

198 **Poore, J. & Nemecek, T.** 2018. Reducing food's environmental impacts through producers and consumers. *Science*, 360(6392): 987–992. https://doi.org/10.1126/science.aaq0216

199 **Börner, J., Schulz, D., Wunder, S. & Pfaff, A.** 2020. The effectiveness of forest conservation policies and programs. *Annual Review of Resource Economics*, 12(1): 45–64. https://doi.org/10.1146/annurev-resource-110119-025703

200 **Rakatama, A., Pandit, R., Ma, C. & Iftekhar, S.** 2017. The costs and benefits of REDD+: A review of the literature. *Forest Policy and Economics*, 75: 103–111. https://doi.org/10.1016/j.forpol.2016.08.006

201 **Leblois, A., Damette, O. & Wolfersberger, J.** 2017. What has driven deforestation in developing countries since the 2000s? Evidence from new remote-sensing data. *World Development*, 92: 82–102. https://doi.org/10.1016/j.worlddev.2016.11.012

202 **Anonymous**. 2020. *Progress on the New York Declaration on Forests Goal 1 assessment*. Climate Focus. (also available at https://forestdeclaration.org/wp-content/uploads/2021/08/2020NYDFGoal1.pdf).

203 **Anonymous**. 2020. *Progress on the New York Declaration on Forests Goal 1 assessment*. Climate Focus. (also available at https://forestdeclaration.org/wp-content/uploads/2021/08/2020NYDFGoal1.pdf).

204 **Gichuki, L., Brouwer, R., Davies, J., Vidal, A., Kuzee, M., Magero, C., Walter, S. *et al.*** 2019. *Reviving land and restoring landscapes – Policy convergence between forest landscape restoration and land degradation neutrality*. International Union for Conservation of Nature. https://doi.org/10.2305/IUCN.CH.2019.11.en

205 **UN Environment Programme, ed.** 2009. *The economics of ecosystems and biodiversity for national and international policy makers – Summary. Responding to the value of nature*. The Economics of Ecosystems & Biodiversity. Geneva, Switzerland. 39 p.

206 **Oberle, B., Bringezu, S., Hatfield-Dodds, S., Hellweg, S., Schandl, H. & Clement, J.** 2019. *Global resources outlook 2019 – Natural resources for the future we want*. Nairobi, UN Environment Programme.

207 **Mirzabaev, A., Sacande, M., Motlagh, F., Shyrokaya, A. & Martucci, A.** 2021. Economic efficiency and targeting of the African Great Green Wall. *Nature Sustainability*. https://doi.org/10.1038/s41893-021-00801-8

208 **Mansuy, N.** 2020. Stimulating post-COVID-19 green recovery by investing in ecological restoration. *Restoration Ecology*, 28(6): 1343–1347. https://doi.org/10.1111/rec.13296

209 **Benayas, J.M.R., Newton, A.C., Diaz, A. & Bullock, J.M.** 2009. Enhancement of biodiversity and ecosystem services by ecological restoration: a meta-analysis. *Science*, 325(5944): 1121–1124. https://doi.org/10.1126/science.1172460

210 **Burek, P., Satoh, Y., Fischer, G., Kahil, M.T., Schertzer, A., Tramberend, S., Fabiola Nava, L. *et al.*** 2016. *Water futures and solution – Fast Track Initiative final report.* 113 p. 16–006. Laxenburg, Austria, International Institute for Applied Systems Analysis. (also available at http://pure.iiasa.ac.at/id/eprint/13008/1/WP-16-006.pdf).

211 **WWAP (UN World Water Assessment Programme)/ UN-Water**. 2018. World Water Development Report 2018. In: *UN-Water* [online]. [Cited 8 November 2021]. https://www.unwater.org/publications/world-water-development-report-2018/

212 **van der Esch, S., Sewell, A., Bakkenes, M., Doelman, J., Stehfest, E., Langhans, C., Fleskens, L. *et al.*** 2021. *The global potential for land restoration – Scenarios for the Global Land Outlook 2. Main messages and executive summary*. The Hague, PBL Netherlands Environmental Assessment Agency.

213 **Stanturf, J., Mansourian, S. & Kleine, M., eds.** 2017. *Implementing forest landscape restoration – A practitioner's guide*. Vienna, International Union of Forest Research Organizations.

214 **Intergovernmental Panel on Climate Change & Edenhofer, O., eds.** 2014. *Climate change 2014 – Mitigation of climate change: Working Group III contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. New York, NY, Cambridge University Press. 1435 pp.

215 **Intergovernmental Panel on Climate Change**. In press. *Summary for Policymakers. In: Climate Change 2021 – The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. V. Masson-Delmotte, P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, et al., eds. Cambridge University Press.

REFERENCES

216 **Witze, A.** 2020. The Arctic is burning like never before – and that's bad news for climate change. *Nature*, 585(7825): 336–337. https://doi.org/10.1038/d41586-020-02568-y

217 **FAO**. 2020. *Peatlands mapping and monitoring – Recommendations and technical overview.* Rome, FAO. https://doi.org/10.4060/ca8200en

218 **Similä, M., Aapala, K., Penttinen, J. & Finnland, eds.** 2014. *Ecological restoration in drained peatlands – Best practices from Finland*. Vantaa, Metsähallitus, Natural Heritage Services [u.a.]. 84 pp.

219 e.g. **Kiely, L., Spracklen, D.V., Arnold, S.R., Papargyropoulou, E., Conibear, L., Wiedinmyer, C., Knote, C. *et al.*** 2021. Assessing costs of Indonesian fires and the benefits of restoring peatland. *Nature Communications*, 12(1): 7044. https://doi.org/10.1038/s41467-021-27353-x

220 **Prosperi, P., Bloise, M., Tubiello, F.N., Conchedda, G., Rossi, S., Boschetti, L., Salvatore, M. *et al.*** 2020. New estimates of greenhouse gas emissions from biomass burning and peat fires using MODIS Collection 6 burned areas. *Climatic Change*, 161(3): 415–432. https://doi.org/10.1007/s10584-020-02654-0

221 **National Interagency Fire Center**. Undated. *Suppression costs | National Interagency Fire Center* [online]. [Cited 14 January 2022]. https://www.nifc.gov/fire-information/statistics/suppression-costs

222 **Government of Canada**. 2021. *Cost of wildland fire protection* [online]. [Cited 19 January 2022]. https://www.nrcan.gc.ca/climate-change/impacts-adaptations/climate-change-impacts-forests/forest-change-indicators/cost-fire-protection/17783

223 **Thomas, D., Butry, D., Gilbert, S., Webb, D. & Fung, J.** 2017. *The costs and losses of wildfires – A literature survey.* NIST SP 1215. Gaithersburg, USA, National Institute of Standards and Technology. https://doi.org/10.6028/NIST.SP.1215

224 **Association for Fire Ecology, International Association of Wildland Fire & The Nature Conservancy**. 2015. *Reduce wildfire risks or we'll continue to pay more for fire disasters – Position statement*. [Cited 18 January 2022]. https://static1.squarespace.com/static/5ea4a2778a22135afc733499/t/5eae000aed72103d3af6301b/1588461581402/True-Costs-of-Wildfire-2.pdf

225 **FAO & Global Mechanism of the UNCCD**. 2015. *Sustainable financing for forest and landscape restoration – Opportunities, challenges and the way forward*. Rome. 114 pp.

226 **UN Environment Programme**. 2021. *State of finance for nature – Tripling investments in nature-based solutions by 2030.* Nairobi.

227 **O'Callaghan, B.J. & Murdock, E.** 2021. *Are we building back better? Evidence from 2020 and pathways to inclusive green recovery spending.* Global Recovery Observatory and UN Environment Programme. 57 pp.

228 **Hepburn, C., O'Callaghan, B., Stern, N., Stiglitz, J. & Zenghelis, D.** 2020. Will COVID-19 fiscal recovery packages accelerate or retard progress on climate change? *Oxford Review of Economic Policy*, 36(Supplement_1): S359–S381. https://doi.org/10.1093/oxrep/graa015

229 **Besseau, P., Graham, S. & Christophersen, T., eds.** 2018. *Restoring forests and landscapes – The key to a sustainable future.* Vienna, Global Partnership on Forest and Landscape Restoration. (also available at https://www.forestlandscaperestoration.org/images/gpflr_final%2027aug.pdf).

230 **Verdone, M. & Seidl, A.** 2017. Time, space, place, and the Bonn Challenge global forest restoration target. *Restoration Ecology*, 25(6): 903–911. https://doi.org/10.1111/rec.12512

231 **Roe, S., Streck, C., Beach, R., Busch, J., Chapman, M., Daioglou, V., Deppermann, A. *et al.*** 2021. Land-based measures to mitigate climate change: potential and feasibility by country. *Global Change Biology*, 27(23): 6025–6058. https://doi.org/10.1111/gcb.15873

232 **Dave, R., Saint-Laurent, C., Murray, L., Antunes Daldegan, G., Brouwer, R., de Mattos Scaramuzza, C.A., Raes, L. *et al.*** 2019. *Second Bonn Challenge progress report – Application of the Barometer in 2018*. International Union for Conservation of Nature. https://doi.org/10.2305/IUCN.CH.2019.06.en

233 **Rudee, A.** 2020. *Want to help the US economy? Rethink the Trillion Trees Act*. (also available at https://www.wri.org/insights/want-help-us-economy-rethink-trillion-trees-act).

234 **ELD Initiative**. 2015. *Report for policy and decision makers - Reaping economic and environmental benefits from sustainable land management*. (also available at https://www.eld-initiative.org/fileadmin/pdf/ELD-pm-report_05_web_300dpi.pdf).

235 **UN Convention to Combat Desertification**. 2020. *The Great Green Wall – Implementation status and way ahead to 2030*. (also available at https://www.unccd.int/publications/great-green-wall-implementation-status-and-way-ahead-2030).

236 **Stanturf, J., Mansourian, S. & Kleine, M., eds.** 2017. *Implementing forest landscape restoration – A practitioner's guide*. Vienna, International Union of Forest Research Organizations.

237 **Dietzel, A., Maes, J., European Commission, Joint Research Centre & Institute for Environment and Sustainability**. 2015. *Costs of restoration measures in the EU based on an assessment of LIFE projects*. Luxembourg, Publications Office. (also available at http://dx.publications.europa.eu/10.2788/235713).

238 **De Groot, R.S., Blignaut, J., Van Der Ploeg, S., Aronson, J., Elmqvist, T. & Farley, J.** 2013. Benefits of investing in ecosystem restoration. *Conservation Biology*, 27(6): 1286–1293. https://doi.org/10.1111/cobi.12158

239 **Birch, J.C., Newton, A.C., Aquino, C.A., Cantarello, E., Echeverría, C., Kitzberger, T., Schiappacasse, I. *et al.*** 2010. Cost-effectiveness of dryland forest restoration evaluated by spatial analysis of ecosystem services. *Proceedings of the National Academy of Sciences of the United States of America*, 107(50): 21925–21930. https://doi.org/10.1073/pnas.1003369107

240 **Bodin, B., Garavaglia, V., Pingault, N., Ding, H., Wilson, S., Meybeck, A., Gitz, V. *et al.*** 2021. A standard framework for assessing the costs and benefits of restoration: introducing The Economics of Ecosystem Restoration. *Restoration Ecology*. https://doi.org/10.1111/rec.13515

241 **Bodin, B., Garavaglia, V., Pingault, N., Ding, H., Wilson, S., Meybeck, A., Gitz, V. *et al.*** 2021. A standard framework for assessing the costs and benefits of restoration: introducing The Economics of Ecosystem Restoration. *Restoration Ecology*. https://doi.org/10.1111/rec.13515

242 **Holl, K.D. & Howarth, R.B.** 2000. Paying for restoration. *Restoration Ecology*, 8(3): 260–267. https://doi.org/10.1046/j.1526-100x.2000.80037.x

243 **Shoo, L.P., Catterall, C.P., Nicol, S., Christian, R., Rhodes, J., Atkinson, P., Butler, D. *et al.*** 2017. Navigating complex decisions in restoration investment. *Conservation Letters*, 10(6): 748–756. https://doi.org/10.1111/conl.12327

244 **Brancalion, P.H.S., Amazonas, N.T., Chazdon, R.L., Melis, J., Rodrigues, R.R., Silva, C.C., Sorrini, T.B. *et al.*** 2020. Exotic eucalypts: from demonized trees to allies of tropical forest restoration? *Journal of Applied Ecology*, 57(1): 55–66. https://doi.org/10.1111/1365-2664.13513

245 **De Groot, R.S., Blignaut, J., Van Der Ploeg, S., Aronson, J., Elmqvist, T. & Farley, J.** 2013. Benefits of investing in ecosystem restoration. *Conservation Biology*, 27(6): 1286–1293. https://doi.org/10.1111/cobi.12158

246 **Kimball, S., Lulow, M., Sorenson, Q., Balazs, K., Fang, Y.-C., Davis, S.J., O'Connell, M. *et al.*** 2015. Cost-effective ecological restoration. *Restoration Ecology*, 23(6): 800–810. https://doi.org/10.1111/rec.12261

247 **International Union for Conservation of Nature**. undated. *Restoration Opportunities Assessment Methodology (ROAM)* | *IUCN* [online]. [Cited 31 December 2021]. https://www.iucn.org/theme/forests/our-work/forest-landscape-restoration/restoration-opportunities-assessment-methodology-roam

248 **International Institute for Sustainability**. undated. *WePlan Forests* [online]. [Cited 31 December 2021]. http://weplan-forests.org/

249 **Beyer, H.L., Williams, B., Schmoeller, M. & Crouzeilles, R.** 2021. *The implications of natural regeneration for tropical and subtropical forest restoration in Colombia, Indonesia, Kenya, Madagascar, Peru and the Philippines*.

250 **Zomer, R.J., Neufeldt, H., Xu, J., Ahrends, A., Bossio, D., Trabucco, A., van Noordwijk, M. *et al.*** 2016. Global tree cover and biomass carbon on agricultural land: the contribution of agroforestry to global and national carbon budgets. *Scientific Reports*, 6(1): 29987. https://doi.org/10.1038/srep29987

251 **Pumariño, L., Sileshi, G.W., Gripenberg, S., Kaartinen, R., Barrios, E., Muchane, M.N., Midega, C. *et al.*** 2015. Effects of agroforestry on pest, disease and weed control: a meta-analysis. *Basic and Applied Ecology*, 16(7): 573–582. https://doi.org/10.1016/j.baae.2015.08.006

252 **Minnemeyer, S., Laestadius, L. & Sizer, N.** 2011. *A world of opportunity*. Washington, DC, World Resource Institute (WRI). (also available at http://pdf.wri.org/world_of_opportunity_brochure_2011-09.pdf).

REFERENCES

253 **Pumariño, L., Sileshi, G.W., Gripenberg, S., Kaartinen, R., Barrios, E., Muchane, M.N., Midega, C. *et al.*** 2015. Effects of agroforestry on pest, disease and weed control: a meta-analysis. *Basic and Applied Ecology*, 16(7): 573–582. https://doi.org/10.1016/j.baae.2015.08.006

254 **Muchane, M.N., Sileshi, G.W., Gripenberg, S., Jonsson, M., Pumariño, L. & Barrios, E.** 2020. Agroforestry boosts soil health in the humid and sub-humid tropics: a meta-analysis. *Agriculture, Ecosystems & Environment*, 295: 106899. https://doi.org/10.1016/j.agee.2020.106899

255 **Udawatta, R.P., Rankoth, L. & Jose, S.** 2019. Agroforestry and biodiversity. *Sustainability*, 11(10): 2879. https://doi.org/10.3390/su11102879

256 **Barral, M.P., Rey Benayas, J.M., Meli, P. & Maceira, N.O.** 2015. Quantifying the impacts of ecological restoration on biodiversity and ecosystem services in agroecosystems: a global meta-analysis. *Agriculture, Ecosystems & Environment*, 202: 223–231. https://doi.org/10.1016/j.agee.2015.01.009

257 **Muchane, M.N., Sileshi, G.W., Gripenberg, S., Jonsson, M., Pumariño, L. & Barrios, E.** 2020. Agroforestry boosts soil health in the humid and sub-humid tropics: a meta-analysis. *Agriculture, Ecosystems & Environment*, 295: 106899. https://doi.org/10.1016/j.agee.2020.106899

258 **Zomer, R.J., Neufeldt, H., Xu, J., Ahrends, A., Bossio, D., Trabucco, A., van Noordwijk, M. *et al.*** 2016. Global tree cover and biomass carbon on agricultural land: the contribution of agroforestry to global and national carbon budgets. *Scientific Reports*, 6(1): 29987. https://doi.org/10.1038/srep29987

259 **Zomer, R.J., Neufeldt, H., Xu, J., Ahrends, A., Bossio, D., Trabucco, A., van Noordwijk, M. *et al.*** 2016. Global tree cover and biomass carbon on agricultural land: the contribution of agroforestry to global and national carbon budgets. *Scientific Reports*, 6(1): 29987. https://doi.org/10.1038/srep29987

260 **Rosenstock, T.S., Wilkes, A., Jallo, C., Namoi, N., Bulusu, M., Suber, M., Mboi, D. *et al.*** 2019. Making trees count: measurement and reporting of agroforestry in UNFCCC national communications of non-Annex I countries. *Agriculture, Ecosystems & Environment*, 284: 106569. https://doi.org/10.1016/j.agee.2019.106569

261 **Lehmann, L.M., Smith, J., Westaway, S., Pisanelli, A., Russo, G., Borek, R., Sandor, M. *et al.*** 2020. Productivity and economic evaluation of agroforestry systems for sustainable production of food and non-food products. *Sustainability*, 12(13): 5429. https://doi.org/10.3390/su12135429

262 **Kuyah, S., Whitney, C.W., Jonsson, M., Sileshi, G.W., Öborn, I., Muthuri, C.W. & Luedeling, E.** 2019. Agroforestry delivers a win-win solution for ecosystem services in sub-Saharan Africa. A meta-analysis. *Agronomy for Sustainable Development*, 39(5): 47. https://doi.org/10.1007/s13593-019-0589-8

263 **Aryal, K., Thapa, P.S. & Lamichhane, D.** 2019. Revisiting agroforestry for building climate resilient communities: a case of package-based integrated agroforestry practices in Nepal. *Emerging Science Journal*, 3(5): 303–311. https://doi.org/10.28991/esj-2019-01193

264 **Lawin, K.G. & Tamini, L.D.** 2019. Land tenure differences and adoption of agri-environmental practices: evidence from Benin. *The Journal of Development Studies*, 55(2): 177–190. https://doi.org/10.1080/00220388.2018.1443210

265 **Ollinaho, O.I. & Kröger, M.** 2021. Agroforestry transitions: the good, the bad and the ugly. *Journal of Rural Studies*, 82: 210–221. https://doi.org/10.1016/j.jrurstud.2021.01.016

266 **Do, H., Luedeling, E. & Whitney, C.** 2020. Decision analysis of agroforestry options reveals adoption risks for resource-poor farmers. *Agronomy for Sustainable Development*, 40(3): 20. https://doi.org/10.1007/s13593-020-00624-5

267 **Charles, R., Munishi, P. & Nzunda, E.** 2013. Agroforestry as adaptation strategy under climate change in Mwanga District, Kilimanjaro, Tanzania. *International Journal of Environmental Protection*, 3: 29–38.

268 **Fisher, M., Chaudhury, M. & McCusker, B.** 2010. Do forests help rural households adapt to climate variability? Evidence from southern Malawi. *World Development*, 38(9): 1241–1250. https://doi.org/10.1016/j.worlddev.2010.03.005

269 **Wunder, S., Börner, J., Shively, G. & Wyman, M.** 2014. Safety nets, gap filling and forests: a global-comparative perspective. *World Development*, 64: S29–S42. https://doi.org/10.1016/j.worlddev.2014.03.005

270 **Magcale-Macandog, D.B., Rañola, F.M., Rañola, R.F., Ani, P.A.B. & Vidal, N.B.** 2010. Enhancing the food security of upland farming households through agroforestry in Claveria, Misamis Oriental, Philippines. *Agroforestry Systems*, 79(3): 327–342. https://doi.org/10.1007/s10457-009-9267-1

271 **Glover, E., Hassan, B.A. & Glover, M.** 2013. Analysis of socio-economic conditions influencing adoption of agroforestry practices. *International Journal of Agriculture and Forestry*, 3: 178–184.

272 **Bettles, J., Battisti, D.S., Cook-Patton, S.C., Kroeger, T., Spector, J.T., Wolff, N.H. & Masuda, Y.J.** 2021. Agroforestry and non-state actors: a review. *Forest Policy and Economics*, 130: 102538. https://doi.org/10.1016/j.forpol.2021.102538

273 **Sollen-Norrlin, M., Ghaley, B.B. & Rintoul, N.L.J.** 2020. Agroforestry benefits and challenges for adoption in Europe and beyond. *Sustainability*, 12(17): 7001. https://doi.org/10.3390/su12177001

274 **Brondizio, E.S.** 2012. Institutional crafting and the vitality of rural areas in an urban world: perspectives from a Japanese community in the Amazon. *Global Environmental Research*, 16(2): 145–151.

275 **Futemma, C., De Castro, F. & Brondizio, E.S.** 2020. Farmers and social innovations in rural development: collaborative arrangements in eastern Brazilian Amazon. *Land Use Policy*, 99: 104999. https://doi.org/10.1016/j.landusepol.2020.104999

276 **Piekielek, J.** 2010. Cooperativism and agroforestry in the eastern Amazon: the case of Tomé-Açu. *Latin American Perspectives*, 37(6): 12–29. https://doi.org/10.1177/0094582X10382097

277 **Ollinaho, O.I. & Kröger, M.** 2021. Agroforestry transitions: the good, the bad and the ugly. *Journal of Rural Studies*, 82: 210–221. https://doi.org/10.1016/j.jrurstud.2021.01.016

278 **Franzel, S., Denning, G.L., Lillesø, J.P.B. & Mercado, A.R.** 2004. Scaling up the impact of agroforestry: lessons from three sites in Africa and Asia. *In*: P.K.R. Nair, M.R. Rao & L.E. Buck, eds. *New vistas in agroforestry*, pp. 329–344. Advances in Agroforestry. Dordrecht, Netherlands, Springer. https://doi.org/10.1007/978-94-017-2424-1_23

279 **Wilson, M. & Lovell, S.** 2016. Agroforestry—the next step in sustainable and resilient agriculture. *Sustainability*, 8(6): 574. https://doi.org/10.3390/su8060574

280 **Robiglio, V. & Reyes, M.** 2016. Restoration through formalization? Assessing the potential of Peru's Agroforestry Concessions scheme to contribute to restoration in agricultural frontiers in the Amazon region. *World Development Perspectives*, 3: 42–46. https://doi.org/10.1016/j.wdp.2016.11.013

281 **Waldén, P., Ollikainen, M. & Kahiluoto, H.** 2020. Carbon revenue in the profitability of agroforestry relative to monocultures. *Agroforestry Systems*, 94(1): 15–28. https://doi.org/10.1007/s10457-019-00355-x

282 **UN Environment Programme**. 2021. *State of finance for nature – Tripling investments in nature-based solutions by 2030*. Nairobi. (also available at https://www.unep.org/resources/state-finance-nature).

283 **UN Environment Programme & FAO**. 2021. *Becoming #GenerationRestoration – Ecosystem restoration for people, nature and climate*. Nairobi (also available at https://wedocs.unep.org/bitstream/handle/20.500.11822/36251/ERPNC.pdf).

284 **Herrick, J.E., Abrahamse, T. & UN Environment Programme**. 2019. *Land restoration for achieving the Sustainable Development Goals – An International Resource Panel think piece.*

285 **Oberle, B., Bringezu, S., Hatfield-Dodds, S., Hellweg, S., Schandl, H. & Clement, J.** 2019. *Global resources outlook 2019 – Natural resources for the future we want*. Nairobi, UN Environment Programme.

286 **Popp, J., Lakner, Z., Harangi-Rákos, M. & Fári, M.** 2014. The effect of bioenergy expansion: food, energy, and environment. *Renewable and Sustainable Energy Reviews*, 32: 559–578. https://doi.org/10.1016/j.rser.2014.01.056

287 **FAO**. undated. *Forest products statistics – Forest product consumption and production* [online]. [Cited 11 November 2021]. https://www.fao.org/forestry/statistics/80938@180723/en/

288 **World Business Council for Sustainable Development**. 2020. *Circular bioeconomy – The business opportunity contributing to a sustainable world*. Geneva, Switzerland. (also available at https://www.wbcsd.org/contentwbc/download/10806/159810/1).

289 **World Bank**. 2016. Housing for all by 2030. Infographics [online]. World Bank. [Cited 8 November 2021]. https://www.worldbank.org/en/news/infographic/2016/05/13/housing-for-all-by-2030

REFERENCES

290 **World Business Council for Sustainable Development**. 2020. *Circular bioeconomy – The business opportunity contributing to a sustainable world.*

291 **Global Alliance for Buildings and Construction, International Energy Agency & UN Environment Programme**. 2019. *2019 Global Status Report for Buildings and Construction Sector – Towards a zero-emission, efficient and resilient buildings and construction sector.* (also available at http://www.unep.org/resources/publication/2019-global-status-report-buildings-and-construction-sector).

292 **Churkina, G., Organschi, A., Reyer, C.P.O., Ruff, A., Vinke, K., Liu, Z., Reck, B.K. *et al.*** 2020. Buildings as a global carbon sink. *Nature Sustainability*, 3(4): 269–276. https://doi.org/10.1038/s41893-019-0462-4

293 **Verkerk, P.J., Hassegawa, M., Van Brusselen, J., Cramm, M., Chen, X., Imparato Maximo, Y., Koç, M. *et al.*** 2021. *Forest products in the global bioeconomy.* Rome, FAO. https://doi.org/10.4060/cb7274en

294 **Ottelin, J., Amiri, A., Steubing, B. & Junnila, S.** 2021. Comparative carbon footprint analysis of residents of wooden and non-wooden houses in Finland. Environmental Research Letters, 16(7): 074006. https://doi.org/10.1088/1748-9326/ac06f9

295 **Stora Enso**. Undated. *10 reasons why wooden buildings are good for you – And the scientific research to back it up.* White paper.

296 **Knox, A. & Parry-Husbands, H.** 2018. *Workplaces – Wellness + wood = productivity.* Forest and Wood Products Australia.

297 **Stay, M.** 2021. Gabon's Special Economic Zone, the world's first certified carbon neutral industrial zone – VivAfrik. In: *New in 24* [online]. [Cited 27 December 2021]. https://new.in-24.com/world/amp/229127

298 **Vussonji, D.C., Makeka, M. & Zwane, C.** Forthcoming. *Building a sustainable circular bioeconomy in Africa through forest products – Trends, opportunities and challenges*. Dalberg Catalyst and FAO.

299 **Makake, M.** 2021. Toward a regenerative forest economy for Gabon. Presentation made at the Yale Forest Forum.

300 **Vussonji, D.C., Makeka, M. & Zwane, C.** Forthcoming. *Building a sustainable circular bioeconomy in Africa through forest products – Trends, opportunities and challenges*. Dalberg Catalyst and FAO.

301 **Secretariat of the Advisory Committee on Sustainable Forest-based Industries**. 2020. *Status of public policies encouraging wood use in construction – An overview*. FAO.

302 **Breneman, S., Timmers, M. & Richardson, D.** 2019. *Tall wood buildings in the 2021 IBC. Up to 18 stories of mass timber.* Wood Products Council. https://www.woodworks.org/wp-content/uploads/wood_solution_paper-TALL-WOOD.pdf

303 **Forest and Wood Products Australia**. 2019. *FWPA drives new National Construction Code changes to increase demand for timber products*. Press release. (also available at https://www.fwpa.com.au/images/mediareleases/2019/FWPA_MR_NCC_2019_Changes_FINAL.pdf).

304 **World Business Council for Sustainable Development**. 2020. *Circular bioeconomy – The business opportunity contributing to a sustainable world*. Geneva, Switzerland. (also available at https://www.wbcsd.org/contentwbc/download/10806/159810/1).

305 **Rotherham, T. & Burrows, J.** 2014. Improvement in efficiency of fibre utilization by the Canadian forest products industry 1970 to 2010. *The Forestry Chronicle*, 90(6): 801–806.

306 **FAO, International Tropical Timber Organization & UN**. 2020. *Forest product conversion factors*. Rome. https://doi.org/10.4060/ca7952en

307 **FAO**. Undated. *FAOSTAT* [online]. [Cited 27 December 2021]. https://www.fao.org/faostat/en/#data/FO

308 **Bais-Moleman, A.L., Sikkema, R., Vis, M., Reumerman, P., Theurl, M.C. & Erb, K.-H.** 2018. Assessing wood use efficiency and greenhouse gas emissions of wood product cascading in the European Union. *Journal of Cleaner Production*, 172: 3942–3954. https://doi.org/10.1016/j.jclepro.2017.04.153

309 **Allott, J., O'Kelly, G. & Pendergraph, S.** 2020. Data: The next wave in forestry productivity | McKinsey. In: *McKinsey & Company* [online]. [Cited 27 December 2021]. https://www.mckinsey.com/industries/paper-forest-products-and-packaging/our-insights/data-the-next-wave-in-forestry-productivity

310 **Ellen MacArthur Foundation**. 2021. *The nature imperative – How the circular economy tackles biodiversity loss*. Ellen MacArthur Foundation. (also available at https://ellenmacarthurfoundation.org/biodiversity-report).

311 **European Commission**. Undated. *Bio-based products*. [online]. Internal market, industry, entrepreneurship and SMEs. [Cited 5 November 2021]. https://ec.europa.eu/growth/sectors/biotechnology/bio-based-products_en

312 **Metreveli, G., Wågberg, L., Emmoth, E., Belák, S., Strømme, M. & Mihranyan, A.** 2014. A size-exclusion nanocellulose filter paper for virus removal. *Advanced Healthcare Materials*, 3(10): 1546–1550. https://doi.org/10.1002/adhm.201300641

313 **University of British Columbia**. 2020. *UBC researchers develop biodegradable medical mask for COVID-19* [online]. [Cited 13 November 2021]. https://news.ubc.ca/2020/05/21/ubc-researchers-develop-biodegradable-medical-mask-for-covid-19/

314 **Claro, F.C., Jordão, C., de Viveiros, B.M., Isaka, L.J.E., Villanova Junior, J.A. & Magalhães, W.L.E.** 2020. Low cost membrane of wood nanocellulose obtained by mechanical defibrillation for potential applications as wound dressing. *Cellulose*, 27(18): 10765–10779. https://doi.org/10.1007/s10570-020-03129-2

315 **UPM**. Undated. *Wood-based FibDex® wound dressing can speed up healing and bring new convenience to patient care | UPM.COM* [online]. [Cited 13 November 2021]. https://www.upm.com/articles/innovations/20/wood-based-fibdex-wound-dressing-can-speed-up-healing-and-bring-new-convenience-to-patient-care/

316 **Smith, T., Majid, F., Eckl, V. & Reynolds, C.M.** 2021. Herbal supplement sales in US increase by record-breaking 17.3% in 2020. *HerbalGram*, (131): 52–65.

317 **European Biomass Industry Association**. Undated. *Biochemicals* [online]. [Cited 27 December 2021]. https://www.eubia.org/cms/wiki-biomass/biochemicals-and-biopolymers/

318 **UN & FAO**. 2021. *Forest Sector Outlook Study 2020–2040*. Geneva Timber and Forest Study Paper 51. Geneva, Switzerland, United Nations. (also available at https://unece.org/sites/default/files/2021-11/SP-51-2021-11_0.pdf).

319 **Verkerk, P.J., Hassegawa, M., Van Brusselen, J., Cramm, M., Chen, X., Imparato Maximo, Y., Koç, M. *et al.*** 2021. *Forest products in the global bioeconomy*. Rome, FAO. https://doi.org/10.4060/cb7274en

320 **ReportLinker**. 2020. *Global cellulosic man-made fibers industry*.

321 **Verkerk, P.J., Hassegawa, M., Van Brusselen, J., Cramm, M., Chen, X., Imparato Maximo, Y., Koç, M. *et al.*** 2021. *Forest products in the global bioeconomy*. Rome, FAO. https://doi.org/10.4060/cb7274en

322 **UN & FAO**. 2021. *Forest Sector Outlook Study 2020–2040*. Geneva Timber and Forest Study Paper 51. Geneva, Switzerland, United Nations. (also available at https://unece.org/sites/default/files/2021-11/SP-51-2021-11_0.pdf).

323 **IEA**. 2021. *Net Zero by 2050. A roadmap for the global energy sector*. IEA. (also available at https://www.iea.org/reports/net-zero-by-2050).

324 **Bailis, R., Drigo, R., Ghilardi, A. & Masera, O.** 2015. The carbon footprint of traditional woodfuels. *Nature Climate Change*, 5(3): 266–272. https://doi.org/10.1038/nclimate2491

325 **ESMAP**. 2012. *Commercial woodfuel production – Experience from three locally controlled wood production models*. Knowledge Series 012/12. World Bank Energy Sector Management Assistance Program. (also available at https://openknowledge.worldbank.org/bitstream/handle/10986/17478/751950ESMAP0WP0el0KS120120Optimized.pdf?sequence=1&isAllowed=y).

326 **FAO**. 2020. *Sustainable charcoal production for food security and forest landscape restoration.* (also available at https://www.fao.org/3/ca7967en/ca7967en.pdf).

327 **Guidal, A., Herail, A. & Rosenstock, T.** 2019. *Feasibility of industrial charcoal production in the Republic of Congo*. Kinshasa, World Agroforestry – ICRAF.

328 **MNREM**. 2017. *National Charcoal Strategy of Malawi (2017–2027)*. Ministry of Natural Resources, Energy and Mining (MNREM), Malawi.

329 **REN21**. 2021. *Renewables 2021 Global Status Report*. REN21 Secretariat. (also available at https://www.ren21.net/wp-content/uploads/2019/05/GSR2021_Full_Report.pdf).

REFERENCES

330 **Lazaridou, D.C., Michailidis, A. & Trigkas, M.** 2021. Exploring environmental and economic costs and benefits of a forest-based circular economy: a literature review. *Forests*, 12(4): 436. https://doi.org/10.3390/f12040436

331 **Raven, P.** 2021. Letter regarding use of forests for bioenergy to President Biden, President von der Leyen, President Michel, Prime Minister Suga, and President Moon.

332 **IEA**. 2021. *Net zero by 2050 – A roadmap for the global energy sector*. International Energy Agency (IEA). (also available at https://www.iea.org/reports/net-zero-by-2050).

333 **CCA**. 2021. *Venture Catalyst* [online]. https://cleancooking.org/venture-catalyst/

334 **Wiebe, K.S., Simas, M. & Harsdorff, M.** Undated. *Measuring the socioeconomic impacts of climate policies to guide NDC enhancement and a just transition*. Nigeria Green Jobs Assessment Report. UN Development Programme and International Labour Organization.

335 **Renner, M.** 2017. *Rural renewable energy investments and their impact on employment*. Strengthen Publication Series Working Paper 1. 95 p. Geneva, Switzerland, International Labour Organization.

336 **OECD**. Undated. *Climate Change: OECD DAC External Development Finance Statistics – OECD* [online]. [Cited 19 January 2022]. https://www.oecd.org/dac/financing-sustainable-development/development-finance-topics/climate-change.htm

337 **Whiteman, A., Wickramasinghe, A. & Piña, L.** 2015. Global trends in forest ownership, public income and expenditure on forestry and forestry employment. *Forest Ecology and Management*, 352: 99–108. https://doi.org/10.1016/j.foreco.2015.04.011

338 **OECD**. 2020. *Towards sustainable land use – Aligning biodiversity, climate and food policies*. Organisation for Economic Co-operation and Development (OECD). https://doi.org/10.1787/3809b6a1-en

339 **UN Environment Programme**. 2021. *State of finance for nature – Tripling investments in nature-based solutions by 2030*. Nairobi.

340 **FAO, UN Development Programme & UN Environment Programme**. 2021. *A multi-billion-dollar opportunity – Repurposing agricultural support to transform food systems*. https://doi.org/10.4060/cb6562en

341 **Vivid Economics & Finance for Biodiversity Initiative**. 2021. *Greenness of Stimulus Index – An assessment of COVID-19 stimulus by G20 countries and other major economies in relation to climate action and biodiversity goals*. (also available at https://a1be08a4-d8fb-4c22-9e4a-2b2f4cb7e41d.filesusr.com/ugd/643e85_f712aba98f0b4786b54c455fc9207575.pdf).

342 **Bottaro, G., Liagre, L. & Pettenella, D.** 2021. *How is the forest sector integrated in the National Recovery and Resilience Plans of EU countries?*

343 **Global Recovery Observatory**. Undated. *Global Recovery Observatory – Oxford University Economic Recovery Project* [online]. [Cited 11 November 2021]. https://recovery.smithschool.ox.ac.uk/tracking/1

344 **Group of Multilateral Development Banks**. 2021. *Joint report on multilateral development banks' climate finance 2020*. London, European Bank for Reconstruction and Development. (also available at https://thedocs.worldbank.org/en/doc/9234bfc633439d0172f6a6eb8df1b881-0020012021/original/2020-Joint-MDB-report-on-climate-finance-Report-final-web.pdf).

345 **Group of Multilateral Development Banks**. 2021. *Joint report on multilateral development banks' climate finance 2020*. London, European Bank for Reconstruction and Development. (also available at https://thedocs.worldbank.org/en/doc/9234bfc633439d0172f6a6eb8df1b881-0020012021/original/2020-Joint-MDB-report-on-climate-finance-Report-final-web.pdf).

346 **Swann, S., Blandford, L., Cheng, S., Cook, J., Miller, A. & Barr, R.** 2021. *Public international funding of nature-based solutions for adaptation – A landscape assessment*. World Resources Institute. https://doi.org/10.46830/wriwp.20.00065

347 **Atteridge, A. & Tenggren, S.** 2019. *Finance for the adaptation of ecosystems to climate change – A review of the Adaptation Fund portfolio*. 28 p. Stockholm, Stockholm Environment Institute.

348 **UN Environment Programme**. 2021. *State of finance for nature – Tripling investments in nature-based solutions by 2030*. Nairobi.

349 **UN Environment Programme**. 2021. *State of finance for nature – Tripling investments in nature-based solutions by 2030*. Nairobi.

350 **World Economic Forum**. 2021. *Investing in forests – The business case*. Geneva, Switzerland. (also available at https://www3.weforum.org/docs/WEF_Investing_in_Forests_2021.pdf).

351 **Castrén, T., Katila, M., Lindroos, K. & Salmi, J.** 2014. *private financing for sustainable forest management and forest products in developing countries—Trends and drivers*. Washington, DC, Program on Forests (PROFOR).

352 **UN Environment Programme.** 2021. *State of finance for nature – Tripling investments in nature-based solutions by 2030*. Nairobi.

353 **Indufor Oy & Criterion Africa Partners**. 2017. *Allocating capital for maximum impact in Africa's plantation forestry sector*. Helsinki.

354 **Held, C.** 2020. *The impact of FLEGT VPAs on forest sector investment risk in Indonesia and Viet Nam*. 24 p. International Tropical Timber Organization.

355 **Forest Europe**. 2020. *State of Europe's Forests 2020*. Ministerial Conference on the Protection of Forests in Europe. (also available at https://foresteurope.org/wp-content/uploads/2016/08/SoEF_2020.pdf).

356 **Forest Europe**. 2020. *State of Europe's Forests 2020*. Ministerial Conference on the Protection of Forests in Europe. (also available at https://foresteurope.org/wp-content/uploads/2016/08/SoEF_2020.pdf).

357 **UN Environment Programme**. 2021. *State of finance for nature – Tripling investments in nature-based solutions by 2030*. Nairobi.

358 **World Bank**. 2020. *Mobilizing private finance for nature*. Washington, DC, World Bank. https://doi.org/10.1596/35984

359 **Elbein, S.** 2020. A new way to profit from ancient Alaskan forests – leave them standing [online]. *National Geographic*. [Cited 12 November 2021]. https://www.nationalgeographic.com/science/article/new-way-to-profit-from-ancient-alaskan-forests-leave-them-standing

360 **World Wide Fund for Nature**. 2020. *Community leaders in Central Vietnam pioneer a sustainable forestry model* [online]. WWF Forest Solutions. [Cited 10 November 2021]. https://forestsolutions.panda.org/insights/community-leaders-in-central-vietnam-pioneer-a-sustainable-forestry-model

361 **World Wide Fund for Nature**. 2017. *Vietnam – Supplying the world with garden furniture, small forest owners in Vietnam could help end deforestation* [online]. [Cited 10 November 2021]. https://wwf.exposure.co/vietnam

362 **Nguyen Vinh Quang, To Xuan Phuc, Basik Treanor, N., Nguyen Ton Quyen & Cao Thi**. 2018. *Linking smallholder plantations to global markets*. Washington, DC, Forest Trends. (also available at https://www.forest-trends.org/publications/linking-smallholder-plantations-to-global-markets/).

363 **Pham, T.T., Nguyen, D.T., Đào Thi, L.C. & Hoàng, T.L.** 2020. *Preparing Vietnam for new rules on international market: Zero deforestation production and business*. Center for International Forestry Research (CIFOR). https://doi.org/10.17528/cifor/007573

364 **Sadanandan Nambiar, E.K.** 2021. Strengthening Vietnam's forestry sectors and rural development: higher productivity, value, and access to fairer markets are needed to support small forest growers. *Trees, Forests and People*, 3: 100052. https://doi.org/10.1016/j.tfp.2020.100052

365 **Organisation for Economic Co-operation and Development**. Undated. *Blended Finance – OECD* [online]. [Cited 28 December 2021]. https://www.oecd.org/dac/financing-sustainable-development/blended-finance-principles/

366 **Blended Finance Taskforce**. Undated. *Tropical Asia Forest Fund 2* [online]. [Cited 10 November 2021]. https://www.blendedfinance.earth/blended-finance-funds/2020/11/16/tropical-asia-forest-fund-2

367 **Green Climate Fund**. Undated. *FP173: The Amazon Bioeconomy Fund: Unlocking private capital by valuing bioeconomy products and services with climate mitigation and adaptation results in the Amazon | Green Climate Fund* [online]. [Cited 28 December 2021]. https://www.greenclimate.fund/project/fp173

368 **Louman, B., Meybeck, A., Mulder, G., Brady, M., Fremy, F., Savenije, H., Gitz, V. *et al.*** 2020. *Innovative finance for sustainable landscapes*. Center for International Forestry Research (CIFOR). https://doi.org/10.17528/cifor/007852

369 **Almeida, M.** 2020. *Green Bonds Global State of the Market 2019*. Climate Bonds Initiative.

REFERENCES

370 **European Commission**. 2021. *€250 billion of NextGenerationEU green bonds* [online]. [Cited 14 November 2021]. https://ec.europa.eu/commission/presscorner/detail/en/ip_21_4565

371 e.g. **FAO**. 2019. *Catalyzing private finance for inclusive and sustainable forest value chains.* Report of the expert meeting. Rome. (also available at https://www.fao.org/forestry/48858-064440fb9719c37f1b7b2a3e957b017c1.pdf); **UN Environment Programme**. Undated. *Private investment for restoration: Addressing the pipeline bottleneck* [online]. [Cited 28 December 2021]. https://www.unep.org/events/webinar/private-investment-restoration-addressing-pipeline-bottleneck

372 **Cunningham, S.A., Attwood, S.J., Bawa, K.S., Benton, T.G., Broadhurst, L.M., Didham, R.K., McIntyre, S. *et al.*** 2013. To close the yield-gap while saving biodiversity will require multiple locally relevant strategies. *Agriculture, Ecosystems & Environment*, 173: 20–27. https://doi.org/10.1016/j.agee.2013.04.007

373 **Foley, J.A., Ramankutty, N., Brauman, K.A., Cassidy, E.S., Gerber, J.S., Johnston, M., Mueller, N.D. *et al.*** 2011. Solutions for a cultivated planet. *Nature*, 478(7369): 337–342. https://doi.org/10.1038/nature10452

374 **Angelsen, A., Kaimowitz, D. & Center for International Forestry Research, eds.** 2001. *Agricultural technologies and tropical deforestation.* New York, USA, CABI Pub. in association with Center for International Forestry Research. 422 p.

375 **World Bank**. 2017. *Harnessing the potential of productive forests and timber supply chains for climate change mitigation and green growth.* Washington, DC. (also available at https://www.climateinvestmentfunds.org/sites/default/files/knowledge-documents/productive_forests_pub_4-3-17web.pdf).

376 **Nambiar, E.K.S.** 2019. Tamm Review: re-imagining forestry and wood business: pathways to rural development, poverty alleviation and climate change mitigation in the tropics. *Forest Ecology and Management*, 448: 160–173. https://doi.org/10.1016/j.foreco.2019.06.014

377 **FAO, UN Development Programme & UN Environment Programme**. 2021. *A multi-billion-dollar opportunity – Repurposing agricultural support to transform food systems*. https://doi.org/10.4060/cb6562en

378 **FAO, UN Development Programme & UN Environment Programme**. 2021. *A multi-billion-dollar opportunity – Repurposing agricultural support to transform food systems*. https://doi.org/10.4060/cb6562en

379 **Whiteman, A., Wickramasinghe, A. & Piña, L.** 2015. Global trends in forest ownership, public income and expenditure on forestry and forestry employment. *Forest Ecology and Management*, 352: 99–108. https://doi.org/10.1016/j.foreco.2015.04.011

380 **World Bank**. 2021. *The Changing Wealth of Nations 2021 – Managing assets for the future*. Washington, DC.

381 **FAO, UN Development Programme & UN Environment Programme**. 2021. *A multi-billion-dollar opportunity – Repurposing agricultural support to transform food systems*. https://doi.org/10.4060/cb6562en

382 **Buttoud, G.** 2012. From PES to REDD: making policy tools and economic mechanisms interact for a better forest governance. *Forest Policy and Economics*, 18: 1–3. https://doi.org/10.1016/j.forpol.2012.03.001

383 **Karsenty, A.** 2021. *Fiscal and non-fiscal incentives for sustainable forest management –Synthesis of the lessons derived from case studies in Brazil, Cambodia, the Congo, Côte d'Ivoire, Myanmar, Peru, Thailand and Viet Nam.* ITTO Technical Series 48. Yokohama, Japan, International Tropical Timber Organization.

384 **Busch, J., Ring, I., Akullo, M., Amarjargal, O., Borie, M., Cassola, R.S., Cruz-Trinidad, A. *et al.*** 2021. A global review of ecological fiscal transfers. *Nature Sustainability*, 4(9): 756–765. https://doi.org/10.1038/s41893-021-00728-0.

385 **Rao, M., Bast, A. & de Boer, A.** 2021. European private food safety standards in global agri-food supply chains: a systematic review. *International Food and Agribusiness Management Review*, 24(5): 739–754. https://doi.org/10.22434/IFAMR2020.0146

386 **Fernandez de Cordoba, S., ed.** 2018. *Voluntary sustainability standards, trade and sustainable development.* UN Forum on Sustainability Standards. (also available at https://unctad.org/system/files/official-document/unfss_3rd_2018_en.pdf).

387 See, for example: **Cerutti, P.O., Goetghebuer, T., Leszczynska, N., Newbery, J., Breyne, J., Dermawan, A., Mauquoy, C. *et al.*** 2020. *Collecting evidence of FLEGT-VPA impacts for improved FLEGT communication.* 79 p. Bogor, Indonesia, Center for International Forestry Research (CIFOR).

388 **Dieterle, G. & Karsenty, A.** 2020. 'Wood security': the importance of incentives and economic valorisation in conserving and expanding forests. *International Forestry Review*, 22(1): 81–92. https://doi.org/10.1505/146554820829523916

389 **Pendrill, F., Persson, U.M., Godar, J., Kastner, T., Moran, D., Schmidt, S. & Wood, R.** 2019. Agricultural and forestry trade drives large share of tropical deforestation emissions. *Global Environmental Change*, 56: 1–10. https://doi.org/10.1016/j.gloenvcha.2019.03.002

390 **Hoang, N.T. & Kanemoto, K.** 2021. Mapping the deforestation footprint of nations reveals growing threat to tropical forests. *Nature Ecology & Evolution*, 5(6): 845–853. https://doi.org/10.1038/s41559-021-01417-z

391 Text of the agreement: **Anonymous**. Undated. Comprehensive Economic Partnership Agreement between the Republic of Indonesia and the EFTA states [online]. [Cited 10 November 2021]. https://www.efta.int/sites/default/files/documents/legal-texts/free-trade-relations/indonesia/efta-indonesia-main-agreement.pdf

392 **Swiss Confederation**. 2021. *Huile de palme durable d'Indonésie: le Conseil fédéral approuve l'ordonnance* [online]. [Cited 10 November 2021]. https://www.admin.ch/gov/fr/accueil/documentation/communiques.msg-id-84740.html

393 **Marchi, V.D., Maria, E.D. & Micelli, S.** 2013. Environmental strategies, upgrading and competitive advantage in global value chains: environmental strategies, upgrading and competitive advantage in GVC. *Business Strategy and the Environment*, 22(1): 62–72. https://doi.org/10.1002/bse.1738

394 **Network for Greening the Finance Sector**. 2021. *NGFS and INSPIRE launch a joint research project on 'Biodiversity and Financial Stability' | Banque de France* [online]. [Cited 14 November 2021]. https://www.ngfs.net/en/communique-de-presse/ngfs-and-inspire-launch-joint-research-project-biodiversity-and-financial-stability

395 **Taskforce on Nature-Related Financial Disclosures**. Undated. *About – TNFD* [online]. [Cited 1 January 2022]. https://tnfd.global/about/

396 **International Civil Aviation Organization**. Undated. *Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)* [online]. [Cited 10 November 2021]. https://www.icao.int/environmental-protection/CORSIA/Pages/default.aspx

397 **Lowering Emissions by Accelerating Forest finance (LEAF) Coalition**. Undated. *The LEAF Coalition* [online]. [Cited 10 November 2021]. https://leafcoalition.org/

398 **Ecosystem Marketplace**. Undated. *Global carbon hub for data and insights on carbon markets and voluntary offsets – Ecosystem Marketplace* [online]. [Cited 10 November 2021]. https://www.ecosystemmarketplace.com/carbon-markets/

399 **Ecosystem Marketplace**. Undated. *Global Carbon Hub for Data and Insights on Carbon Markets and Voluntary Offsets - Ecosystem Marketplace* [online]. [Cited 10 November 2021]. https://www.ecosystemmarketplace.com/carbon-markets/

400 **World Bank**. 2017. Harnessing the potential of productive forests and timber supply chains for climate change mitigation and green growth. Washington, DC. (also available at https://www.climateinvestmentfunds.org/sites/default/files/knowledge-documents/productive_forests_pub_4-3-17web.pdf).

401 **Green Climate Fund**. Undated. *Portfolio dashboard | Green Climate Fund* [online]. [Cited 28 December 2021]. https://www.greenclimate.fund/projects/dashboard

402 **Nesha, M.K., Herold, M., De Sy, V., Duchelle, A.E., Martius, C., Branthomme, A., Garzuglia, M. *et al.*** 2021. An assessment of data sources, data quality and changes in national forest monitoring capacities in the Global Forest Resources Assessment 2005–2020. *Environmental Research Letters*, 16(5): 054029. https://doi.org/10.1088/1748-9326/abd81b

403 **Nesha, M.K., Herold, M., De Sy, V., Duchelle, A.E., Martius, C., Branthomme, A., Garzuglia, M. *et al.*** 2021. An assessment of data sources, data quality and changes in national forest monitoring capacities in the Global Forest Resources Assessment 2005–2020. *Environmental Research Letters*, 16(5): 054029. https://doi.org/10.1088/1748-9326/abd81b

404 **Nesha, M.K., Herold, M., De Sy, V., Duchelle, A.E., Martius, C., Branthomme, A., Garzuglia, M. *et al.*** 2021. An assessment of data sources, data quality and changes in national forest monitoring capacities in the Global Forest Resources Assessment 2005–2020. *Environmental Research Letters*, 16(5): 054029. https://doi.org/10.1088/1748-9326/abd81b

405 **Chagas, T., Galt, H., Lee, D., Neeff, T. & Streck, C.** 2020. *A close look at the quality of REDD+ carbon credits*. (also available at https://www.climatefocus.com/publications/close-look-quality-redd-carbon-credits).

REFERENCES

406 **Macqueen, D., Benni, N., Boscolo, M. & Zapata, J.** 2018. *Access to finance for forest and farm producer organisations (FFPOs)*. Rome, FAO and London, International Institute for Environment and Development.

407 **FAO**. 2019. *Catalyzing private finance for inclusive and sustainable forest value chains – Report of the expert meeting* [online]. [Cited 26 November 2021]. https://www.fao.org/forestry/48858-064440fb9719c37f1b7b2a3e957b017c1.pdf

408 **Lowder, S.K., Sánchez, M.V. & Bertini, R.** 2021. Which farms feed the world and has farmland become more concentrated? *World Development*, 142: 105455. https://doi.org/10.1016/j.worlddev.2021.105455

409 **Chiriac, D. & Naran, B.** 2020. *Examining the climate finance gap for small-scale agriculture*. Climate Policy Initiative. (also available at https://www.climatepolicyinitiative.org/publication/climate-finance-small-scale-agriculture/).

410 **Rainforest Foundation Norway**. 2021. *Falling short – Donor funding for Indigenous Peoples and local communities to secure tenure rights and manage forests in tropical countries (2011-2020)*. Oslo, Rainforest Foundation Norway. (also available at https://www.cwis.org/document/falling-short-donor-funding-for-indigenous-peoples-and-local-communities-to-secure-tenure-rights-and-manage-forests-in-tropical-countries-2011-2020/).

411 **Anonymous**. 2021. Governments and private funders announce historic US$1.7 billion pledge at COP26 in support of Indigenous Peoples and local communities / Ford Foundation. In: *Ford Foundation* [online]. [Cited 2 February 2022]. https://www.fordfoundation.org/news-and-stories/news-and-press/news/governments-and-private-funders-announce-historic-us-17-billion-pledge-at-cop26-in-support-of-indigenous-peoples-and-local-communities/

412 **Starfinger, M.** 2021. Financing smallholder tree planting: tree collateral & Thai 'Tree Banks' – Collateral 2.0? *Land Use Policy*, 111: 105765. https://doi.org/10.1016/j.landusepol.2021.105765

413 **Nugroho, B., Soedomo, S. & Dermawan, A.** 2017. Policy effectiveness of loan for delaying timber harvesting for smallholder private forest in Indonesia. *Jurnal Manajemen Hutan Tropika (Journal of Tropical Forest Management)*, 23(2): 61–70. https://doi.org/10.7226/jtfm.23.2.61

414 **RECOFTC**. 2015. *Access to information for securing resource and tenure rights Houaythong Village, Lao PDR*. First edition. Equity Case Study Brief. RECOFTC.

415 **Parthiban, K.T., Seenivasan, R., Vennila, S., Anbu, P.V., Kumar, P., Saravanan, V., Umesh Kanna, S. *et al.*** 2011. Designing and augmenting pulpwood supply chain through contract tree farming. *Indian Journal of Ecology*, 38(Special issue): 41–47.

416 **Byakagaba, P., Okullo, J.B.L., Eilu, G. & Mwavu, E.N.** 2021. The role of fallowing in the restoration of woody species in the woodlands of northern Uganda. *African Journal of Ecology*, aje.12895. https://doi.org/10.1111/aje.12895

417 **Lawrence, D. & Louman, B.** 2021. *Finance for integrated landscape management – A landscape approach to climate-smart cocoa in the Juabeso-Bia Landscape, Ghana*. Tropenbos Ghana and Tropenbos International. (also available at https://www.tropenbos.org/file.php/2462/finance-integrated-landscape-mangement-touton-ghana.pdf).

418 **Durbin, J., King, D., Calderwood, N., Wells, Z. & Godoy, F.** 2019. *Benefit sharing at scale – Good practices for results-based land use programs*. Washington, DC, World Bank. https://doi.org/10.1596/32765

419 **Bertzky, M., Canosa, O., Koch, A. & Llopis, P.** 2021. *Assessment report – Comparative analysis of benefit-sharing mechanisms in REDD+ programs*. World Wide Fund for Nature. (also available at https://wwfint.awsassets.panda.org/downloads/wwf_assessment_report_redd__programs_v4.pdf).

420 **Lowder, S.K., Sánchez, M.V. & Bertini, R.** 2021. Which farms feed the world and has farmland become more concentrated? *World Development*, 142: 105455. https://doi.org/10.1016/j.worlddev.2021.105455

421 **World Wide Fund for Nature, UN Environment Programme, World Conservation Monitoring Centre, GEF Small Grants Programme, ICCA-Global Support Initiative, LandMark Global Platform of Indigenous and Community Lands, The Nature Conservancy, Conservation International, Wildlife Conservation Society *et al.*** 2021. *The state of the Indigenous Peoples and local communities lands and territories*. Gland, Switzerland. (also available at https://wwflac.awsassets.panda.org/downloads/report_the_state_of_the_indigenous_peoples_and_local_communities_lands_and_territories_1.pdf).

422 **Verdone, M.** 2018. *The world's largest private sector? Recognising the cumulative economic value of small-scale forest and farm producers*. International Union for Conservation of Nature.

423 **PROFOR**. 2019. *Unlocking the potential of small and medium forest enterprises* [online]. [Cited 10 November 2021]. https://www.profor.info/knowledge/unlocking-potential-small-and-medium-forest-enterprises

424 **Mayers, J.** 2006. Small and medium-sized forestry enterprises. *Tropical Forest Update*, 16(2): 10–11.

425 **Garnett, S.T., Burgess, N.D., Fa, J.E., Fernández-Llamazares, Á., Molnár, Z., Robinson, C.J., Watson, J.E.M. *et al.*** 2018. A spatial overview of the global importance of Indigenous lands for conservation. *Nature Sustainability*, 1(7): 369–374. https://doi.org/10.1038/s41893-018-0100-6

426 **Kruid, S., Macedo, M.N., Gorelik, S.R., Walker, W., Moutinho, P., Brando, P.M., Castanho, A. *et al.*** 2021. Beyond deforestation: carbon emissions from land grabbing and forest degradation in the Brazilian Amazon. *Frontiers in Forests and Global Change*, 4: 645282. https://doi.org/10.3389/ffgc.2021.645282

427 **Alejo, C., Meyer, C., Walker, W.S., Gorelik, S.R., Josse, C., Aragon-Osejo, J.L., Rios, S. *et al.*** 2021. Are indigenous territories effective natural climate solutions? A neotropical analysis using matching methods and geographic discontinuity designs. *PLOS ONE*, 16(7): e0245110. https://doi.org/10.1371/journal.pone.0245110

428 **Walker, W.S., Gorelik, S.R., Baccini, A., Aragon-Osejo, J.L., Josse, C., Meyer, C., Macedo, M.N. *et al.*** 2020. The role of forest conversion, degradation, and disturbance in the carbon dynamics of Amazon indigenous territories and protected areas. *Proceedings of the National Academy of Sciences*, 117(6): 3015–3025. https://doi.org/10.1073/pnas.1913321117

429 **Blackman, A. & Veit, P.** 2018. Titled Amazon indigenous communities cut forest carbon emissions. *Ecological Economics*, 153: 56–67. https://doi.org/10.1016/j.ecolecon.2018.06.016

430 **FAO & FILAC**. 2021. *Forest governance by indigenous and tribal peoples – An opportunity for climate action in Latin America and the Caribbean*. FAO. https://doi.org/10.4060/cb2953en

431 **Baragwanath, K. & Bayi, E.** 2020. Collective property rights reduce deforestation in the Brazilian Amazon. *Proceedings of the National Academy of Sciences*, 117(34): 20495–20502. https://doi.org/10.1073/pnas.1917874117

432 **Blackman, A. & Veit, P.** 2018. Titled Amazon indigenous communities cut forest carbon emissions. *Ecological Economics*, 153: 56–67. https://doi.org/10.1016/j.ecolecon.2018.06.016

433 **Ding, H., Veit, P., Gray, E., Reytar, K., Altamirano-Cabrera, J.-C., Blackman, A. & Hodgdon, B.** 2016. *Climate benefits, tenure costs – The economic case for securing indigenous land rights in the Amazon.*

434 **FAO and FILAC**. 2021. *Forest governance by indigenous and tribal peoples – An opportunity for climate action in Latin America and the Caribbean*. FAO. https://doi.org/10.4060/cb2953en

435 **Tauli-Corpuz, V., Alcorn, J., Molnar, A., Healy, C. & Barrow, E.** 2020. Cornered by PAs: adopting rights-based approaches to enable cost-effective conservation and climate action. *World Development*, 130: 104923. https://doi.org/10.1016/j.worlddev.2020.104923

436 **Ding, H., Veit, P., Gray, E., Reytar, K., Altamirano-Cabrera, J.-C., Blackman, A. & Hodgdon, B.** 2016. *Climate benefits, tenure costs – The economic case for securing indigenous land rights in the Amazon.*

437 **World Wide Fund for Nature, UN Environment Programme World Conservation Monitoring Centre, GEF Small Grants Programme, ICCA-Global Support Initiative, LandMark Global Platform of Indigenous and Community Lands, The Nature Conservancy, Conservation International, Wildlife Conservation Society *et al.*** 2021. *The state of the indigenous peoples and local communities' lands and territories – A technical review of the state of Indigenous Peoples' and Local Communities' lands, their contributions to global biodiversity conservation and ecosystem services, the pressures they face, and recommendations for actions.* Gland, Switzerland. (also available at https://wwflac.awsassets.panda.org/downloads/report_the_state_of_the_indigenous_peoples_and_local_communities_lands_and_territories_1.pdf).

438 **Rights and Resources Initiative, Woodwell Climate Research Center & Rainforest Foundation US**. 2021. *Significance of community-held territories in 24 countries to global climate.* Policy brief. Rights and Resources Initiative. https://doi.org/10.53892/YBGF2711

REFERENCES

439 **Dawson, N.M., Coolsaet, B., Sterling, E.J., Loveridge, R., Gross-Camp, N.D., Wongbusarakum, S., Sangha, K.K. *et al.*** 2021. The role of Indigenous peoples and local communities in effective and equitable conservation. *Ecology and Society*, 26(3): art19. https://doi.org/10.5751/ES-12625-260319

440 **Aggarwal, S., Larson, A., McDermott, C., Katila, P. & Giessen, L.** 2021. Tenure reform for better forestry: an unfinished policy agenda. *Forest Policy and Economics*, 123: 102376. https://doi.org/10.1016/j.forpol.2020.102376

441 **Gilmour, D.A.** 2016. *Forty years of community-based forestry – A review of its extent and effectiveness*. FAO Forestry Paper 176. Rome, FAO. (also available at https://bit.ly/3B1F5lH).

442 **Baynes, J., Herbohn, J., Smith, C., Fisher, R. & Bray, D.** 2015. Key factors which influence the success of community forestry in developing countries. *Global Environmental Change*, 35: 226–238. https://doi.org/10.1016/j.gloenvcha.2015.09.011

443 **FAO & ICRAF**. 2019. *Agroforestry and tenure*. Forestry Working Paper 8. Rome, FAO. 40 p.

444 **Kraus, S., Liu, J., Koch, N. & Fuss, S.** 2021. No aggregate deforestation reductions from rollout of community land titles in Indonesia yet. *Proceedings of the National Academy of Sciences*, 118(43): e2100741118. https://doi.org/10.1073/pnas.2100741118

445 **Hajjar, R., Newton, P., Ihalainen, M., Agrawal, A. & Gabay, M.** 2020. Levers for alleviating poverty in forests and tree-based systems. *Forests, trees and the eradication of poverty – Potential and limitations*, pp. 125–176. IUFRO World Series 39. International Union of Forest Research Organizations.

446 **Miller, D.C., Rana, P., Nakamura, K., Irwin, S., Cheng, S.H., Ahlroth, S. & Perge, E.** 2021. A global review of the impact of forest property rights interventions on poverty. *Global Environmental Change*, 66: 102218. https://doi.org/10.1016/j.gloenvcha.2020.102218

447 **Hajjar, R., Newton, P., Ihalainen, M., Agrawal, A. & Gabay, M.** 2020. Levers for alleviating poverty in forests and tree-based systems. *Forests, trees and the eradication of poverty – Potential and limitations*, pp. 125–176. IUFRO World Series 39. International Union of Forest Research Organizations.

448 **Barrow, E., Kamugisha-Ruhombe, J., Nhantumbo, I., Oyono, R. & Savadogo, M.** 2016. Who owns Africa's forests? Exploring the impacts of forest tenure reform on forest ecosystems and livelihoods. *Forests, Trees and Livelihoods*, 25(2): 132–156. https://doi.org/10.1080/14728028.2016.1159999

449 **De Royer, S., Van Noordwijk, M. & Roshetko, J.M.** 2018. Does community-based forest management in Indonesia devolve social justice or social costs? *International Forestry Review*, 20(2): 167–180. https://doi.org/10.1505/146554818823767609

450 **Namubiru-Mwaura, E.** 2014. *Land tenure and gender – Approaches and challenges for strengthening rural women's land rights.* 36 p. Women's Voice, Agency, & Participation Research Series 6. Washington, DC, World Bank.

451 **Elias, M., Hummel, S.S., Basnett, B.S. & Colfer, C.J.P.** 2017. Gender bias affects forests worldwide. *Ethnobiology Letters*, 8(1). https://doi.org/10.14237/ebl.8.1.2017.834

452 **Hajjar, R., Newton, P., Ihalainen, M., Agrawal, A. & Gabay, M.** 2020. Levers for alleviating poverty in forests and tree-based systems. *Forests, trees and the eradication of poverty – Potential and limitations*, pp. 125–176. IUFRO World Series 39. International Union of Forest Research Organizations.

453 **Blomley, T.** 2013. *Lessons learned from community forestry in Africa and their relevance for REDD+*. Washington, DC, USAID-supported Forest Carbon, Markets and Communities Program. (also available at https://www.climatelinks.org/sites/default/files/asset/document/CF_Africa.pdf).

454 **FAO & Fund for the Development of the Indigenous Peoples of Latin America, and the Caribbean**. 2021. *Forest governance by indigenous and tribal peoples – An opportunity for climate action in Latin America and the Caribbean*. FAO. https://doi.org/10.4060/cb2953en

455 **Gilmour, D.A.** 2016. *Forty years of community-based forestry – A review of its extent and effectiveness*. FAO Forestry Paper 176. Rome, FAO. (also available at https://bit.ly/3B1F5lH).

456 **FAO, ed.** 2012. *Voluntary guidelines on the responsible governance of tenure of land, fisheries and forests in the context of national food security*. Rome. 40 pp.

457 **Alden Wily, L.** 2018. collective land ownership in the 21st century: overview of global trends. *Land*, 7(2): 68. https://doi.org/10.3390/land7020068

458 **Alden Wily, L.** 2018. Collective land ownership in the 21st century: overview of global trends. *Land*, 7(2): 68. https://doi.org/10.3390/land7020068

459 **Government of India Ministry of Tribal Affairs.** 2021. *Monthly update on status of implementation of the Scheduled Tribes and Other Traditional Forest Dweller (Recognition of Forest Rights) Act, 2006*. Delhi. (also available at https://tribal.nic.in/FRA/data/MPRJan2020.pdf).

460 **Freudenberger, M.S.** 2013. *The future of customary tenure – Options for policymakers*. USAID Issue Brief. USAID. (also available at https://www.land-links.org/wp-content/uploads/2016/09/USAID_Land_Tenure_Customary_Tenure_Brief_0-1.pdf).

461 **Fitzpatrick, D.** 2005. 'Best practice' options for the legal recognition of customary tenure. *Development and Change*, 36(3): 449–475. https://doi.org/10.1111/j.0012-155X.2005.00419.x

462 **Government of India**. 2007. The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006. [Cited 29 November 2021]. https://www.fra.org.in/document/FRA%20ACT-Eng.pdf

463 **Blackman, A., Corral, L., Lima, E.S. & Asner, G.P.** 2017. Titling indigenous communities protects forests in the Peruvian Amazon. *Proceedings of the National Academy of Sciences*, 114(16): 4123–4128. https://doi.org/10.1073/pnas.1603290114

464 **FAO**. Undated. *Governance of tenure – SOLA Suite* [online]. [Cited 10 November 2021]. https://www.fao.org/tenure/sola-suite/en

465 **Bouvier, I., Brooks, S., Green, J., Lowery, S. & Stevens, C.** 2019. *Using participatory approaches and innovative technology to empower communities in securing their land*. Paper prepared for presentation at the Annual World Bank Conference on Land and Poverty, 25 March 2019, Washington, DC. (also available at https://www.land-links.org/wp-content/uploads/2019/03/using-participatory-approaches-and-innovative-technology-to-empower-communities-in-securing-their-land.pdf).

466 **Gilmour, D.A.** 2016. *Forty years of community-based forestry – A review of its extent and effectiveness*. FAO Forestry Paper 176. Rome, FAO. (also available at https://bit.ly/3B1F5lH).

467 **Aggarwal, S., Larson, A., McDermott, C., Katila, P. & Giessen, L.** 2021. Tenure reform for better forestry: an unfinished policy agenda. *Forest Policy and Economics*, 123: 102376. https://doi.org/10.1016/j.forpol.2020.102376

468 **Aggarwal, S., Larson, A., McDermott, C., Katila, P. & Giessen, L.** 2021. Tenure reform for better forestry: an unfinished policy agenda. *Forest Policy and Economics*, 123: 102376. https://doi.org/10.1016/j.forpol.2020.102376

469 **Nhantumbo, I., Macqueen, D., Cruz, R. & Serra, A.** 2013. *Investing in locally controlled forestry in Mozambique – Potential for promoting sustainable rural development in the province of Niassa*. London, International Institute for Environment and Development. 92 p. (also available at https://pubs.iied.org/sites/default/files/pdfs/migrate/13569IIED.pdf).

470 **Sonko, K.N. & Camara, K.** 2000. Community forestry implementation in the Gambia: its principles and prospects. *Proceedings of the International Workshop on Community Forestry in Africa. Participatory Forest Management: A Strategy for Sustainable Forest Management in Africa*. (also available at https://www.fao.org/3/X7760B/X7760B00.htm).

471 **Lawry, S., McLain, R., Swallow, B. & Biedenweg, K.** 2012. *Devolution of forest rights and sustainable forest management. Volume 1 – A review of policies and programs in 16 developing countries*. USAID. (also available at https://www.land-links.org/wp-content/uploads/2016/09/USAID_Land_Tenure_Devolution_of_Forest_Rights_and_Sustainable_Forest_Management_Volume_1.pdf).

472 **McFarland, W., Whitley, S. & Kissinger, G.** 2015. *Subsidies to key commodities driving forest loss*. 51 p. ODI Working Paper. Overseas Development Institute.

473 **Tetra Tech**. 2017. *Promoting trees outside forests – Action-learning pilot program in Hoshangabad landscape*. USAID. 29 pp.

474 **McLain, R., Lawry, S., Guariguata, M.R. & Reed, J.** 2021. Toward a tenure-responsive approach to forest landscape restoration: a proposed tenure diagnostic for assessing restoration opportunities. *Land Use Policy*, 104: 103748. https://doi.org/10.1016/j.landusepol.2018.11.053

475 **FAO & ICRAF**. 2019. *Agroforestry and tenure*. Forestry Working Paper 8. Rome. 40 pp.

476 **UN Economic Commission for Europe & FAO**. 2019. *Who owns our forests? Forest ownership in the ECE region*. Geneva, Switzerland. (also available at http://www.unece.org/fileadmin/DAM/timber/publications/SP-43.pdf).

REFERENCES

477 **Koffi, G. & Worms, P.** 2021. *Niger formally adopts farmer-managed natural regeneration* [online]. ICRAF. [Cited 20 October 2021]. https://bit.ly/3nfHRix

478 **UN**. Undated. Farmer Managed Natural Regeneration (FMNR): a technique to effectively combat poverty and hunger through land and vegetation restoration. In: *United Nations Partnerships for SDGs platform* [online]. [Cited 16 December 2021]. https://sustainabledevelopment.un.org/partnership/?p=30735

479 **Stickler, M.** 2012. *Rights to trees and livelihoods in Niger – Focus on land in Africa*. World Resource Institute and Landesa.

480 **Crouzeilles, R., Ferreira, M.S., Chazdon, R.L., Lindenmayer, D.B., Sansevero, J.B.B., Monteiro, L., Iribarrem, A. *et al.*** 2017. Ecological restoration success is higher for natural regeneration than for active restoration in tropical forests. *Science Advances*, 3(11): e1701345. https://doi.org/10.1126/sciadv.1701345

481 **FAO**. 2021. *Society, economy and forests – The unfolding forest transition in China and the lessons for the future*. Bangkok. https://doi.org/10.4060/cb3232en

482 **Wang, L.** 2012. *Success cases and good practices in forest farmer cooperative organizations in China*. Rome, Italy, FAO. 32 pp. (also available at https://www.fao.org/publications/card/en/c/ff2dfab2-03dc-56b9-b5e4-fabdb28cb467/).

483 **FAO**. 2020. *Forest product consumption and production* [online]. [Cited 13 November 2021]. https://www.fao.org/forestry/statistics/80938@180723/en/

484 **He, J., Kebede, B., Martin, A. & Gross-Camp, N.** 2020. Privatization or communalization: a multi-level analysis of changes in forest property regimes in China. *Ecological Economics*, 174: 106629. https://doi.org/10.1016/j.ecolecon.2020.106629

485 **Midgley, S.J., Stevens, P.R. & Arnold, R.J.** 2017. Hidden assets: Asia's smallholder wood resources and their contribution to supply chains of commercial wood. *Australian Forestry*, 80(1): 10–25. https://doi.org/10.1080/00049158.2017.1280750

486 **Hoang, H.T.N., Hoshino, S., Onitsuka, K. & Maraseni, T.** 2019. Cost analysis of FSC forest certification and opportunities to cover the costs a case study of Quang Tri FSC group in Central Vietnam. *Journal of Forest Research*, 24(3): 137–142. https://doi.org/10.1080/13416979.2019.1610993

487 **Nambiar, E.K.S.** 2021. Strengthening Vietnam's forestry sectors and rural development: higher productivity, value, and access to fairer markets are needed to support small forest growers. *Trees, Forests and People*, 3: 100052. https://doi.org/10.1016/j.tfp.2020.100052

488 **Pretty, J., Attwood, S., Bawden, R., van den Berg, H., Bharucha, Z.P., Dixon, J., Flora, C.B. *et al.*** 2020. Assessment of the growth in social groups for sustainable agriculture and land management. *Global Sustainability*, 3: e23. https://doi.org/10.1017/sus.2020.19

489 **Pretty, J., Attwood, S., Bawden, R., van den Berg, H., Bharucha, Z.P., Dixon, J., Flora, C.B. *et al.*** 2020. Assessment of the growth in social groups for sustainable agriculture and land management. *Global Sustainability*, 3: e23. https://doi.org/10.1017/sus.2020.19

490 **Fisher, M.R., Moeliono, M., Mulyana, A., Yuliani, E.L., Adriadi, A., Kamaluddin, Judda, J. *et al.*** 2018. Assessing the new social forestry project in Indonesia: recognition, livelihood and conservation? *International Forestry Review*, 20(3): 346–361. https://doi.org/10.1505/146554818824063014

491 **Segura Warnholtz, G., Fernández, M., Smyle, J. & Springer, J.** 2017. *Securing forest tenure rights for rural development – Lessons from six countries in Latin America*. Washington, DC, Program on Forests. (also available at http://hdl.handle.net/10986/26301).

492 **Paudel, N.S., Monterroso, I. & Cronkleton, P.** 2012. Secondary level organisations and the democratisation of forest governance: case studies from Nepal and Guatemala. *Conservation & Society*, 10(2): 124–135. (also available at https://www.conservationandsociety.org.in/articlecited.asp?issn=0972-4923;year=2012;volume=10;issue=2;spage=124;epage=135;aulast=Paudel;type=3;aid=ConservatSoc_2012_10_2_124_97485).

493 **FAO**. 2016. *Reducing rural poverty through farmer-to-farmer exchange*. Rome. 4 pp. (also available at https://www.fao.org/publications/card/en/c/66915227-169e-42cb-8b1a-32045c6f1f8c/).

494 **Nightingale, A.J.** 2018. The socioenvironmental state: political authority, subjects, and transformative socionatural change in an uncertain world. *Environment and Planning E: Nature and Space*, 1(4): 688–711. https://doi.org/10.1177/2514848618816467

495 **Covey, J., Macqueen, D., Bolin, A. & Hou Jones, X.** 2021. Co-producing knowledge: a demand-led, prosperity-focused, research agenda with forest and farm producer organisations. *Environmental Science & Policy*, 124: 336–347. https://doi.org/10.1016/j.envsci.2021.07.006

496 **Stickler, C., Duchelle, A., Ardila, J.P., David, O., Chan, C., Rojas, J.G., Bezerra, T. *et al.*** 2018. *The state of jurisdictional sustainability – Synthesis for practitioners and policymakers*. San Francisco, USA, Earth Innovation Institute, Center for International Forestry Research and Governor's Climate and Forests Task Force Secretariat. 20 p. (also available at https://earthinnovation.org/wp-content/uploads/2018/09/Stickler_et_al_2018_StateJS_Synthesis_small.pdf).

497 **Stickler, C., Duchelle, A., Ardila, J.P., David, O., Chan, C., Rojas, J.G., Bezerra, T. *et al.*** 2018. *The state of jurisdictional sustainability – Synthesis for practitioners and policymakers*. San Francisco, USA, Earth Innovation Institute, Center for International Forestry Research and Governor's Climate and Forests Task Force Secretariat. 20 p. (also available at https://earthinnovation.org/wp-content/uploads/2018/09/Stickler_et_al_2018_StateJS_Synthesis_small.pdf).

498 **IDH**. 2015. *Mato Grosso set to achieve inclusive green growth* [online]. [Cited 1 January 2022]. https://www.idhsustainabletrade.com/news/mato-grosso-set-achieve-inclusive-green-growth/

499 **Tropical Forest Alliance**. 2021. *Jurisdictional approach to sustainability – Lessons learnt from private sector action in Aceh Tamiang, Indonesia*. (also available at https://www.tropicalforestalliance.org/assets/Uploads/AcehTamiang_Case_study-July2021-Final.pdf).

500 **National Forestry and Grassland Administration**. 2020. *Twenty years' restoration of forests and grasslands from farmland in China*.

501 **Xie, C.** 2017. *Links between social protection and forestry policies – Lessons from China*. Social Protection and Forestry Working Paper 4. FAO. 44 p.

502 **d'Andrea, M., Ma, Q., Ocampo, A. & Omar, B.** Undated. Expanding social protection in rural areas, focusing on fisheries and forestry. *Policy in Focus*, 17(2): 34–37. (also available at https://ipcig.org/pub/eng/PIF45_Universal_social_protection_a_target_for_all.pdf).

503 **National Forestry and Grassland Administration**. 2019. *A report for monitoring and assessment of the socio-economic impacts of China's key forestry programs*. Beijing, China Forestry Publishing House.

504 **National Forestry and Grassland Administration**. 2020. *China forestry and grassland development report.* Beijing, China Forestry Publishing House.

505 **Dodds, R., Ali, A. & Galaski, K.** 2018. Mobilizing knowledge: determining key elements for success and pitfalls in developing community-based tourism. *Current Issues in Tourism*, 21(13): 1547–1568. https://doi.org/10.1080/13683500.2016.1150257

506 **Asare-Nuamah, P., Botchway, E. & Onumah, J.A.** 2019. Helping the helpless: contribution of rural extension services to smallholder farmers' climate change adaptive capacity and adaptation in rural Ghana. *International Journal of Rural Management*, 15(2): 244–268. https://doi.org/10.1177/0973005219876211

507 **Hunt, W., Birch, C., Coutts, J. & Vanclay, F.** 2012. The many turnings of agricultural extension in Australia. *The Journal of Agricultural Education and Extension*, 18(1): 9–26. https://doi.org/10.1080/1389224X.2012.638780

508 **Yusuf, A.S, Adeyemi, T.O, Adeleye, A.S, Bakpolor, V.R, Adegboyega, D.A & Adetola, O.O**. 2020. Impacts of agriculture and forestry in the control of climate change: the role of extension services. *International Journal on Integrated Education*, 3(10): 71–75. https://doi.org/10.31149/ijie.v3i10.681

509 **Czapiewski, K. & Janc, K.** 2019. Education, human capital and knowledge – the paradigm shift and future scenarios on Polish rural areas. *In*: J. Bański, ed. *Three decades of transformation in the East-Central European countryside*, pp. 351–367. Cham, Switzerland, Springer International Publishing. https://doi.org/10.1007/978-3-030-21237-7_16

510 **Kanwar, A., Balasubramanian, K. & Carr, A.** 2019. Changing the TVET paradigm: new models for lifelong learning. *International Journal of Training Research*, 17(sup1): 54–68. https://doi.org/10.1080/14480220.2019.1629722

511 **Covey, J., Macqueen, D., Bolin, A. & Hou Jones, X.** 2021. Co-producing knowledge: a demand-led, prosperity-focused, research agenda with forest and farm producer organisations. *Environmental Science & Policy*, 124: 336–347. https://doi.org/10.1016/j.envsci.2021.07.006

REFERENCES

512 **FAO**. 2019. *Farmers taking the lead – Thirty years of farmer field schools*. Rome. 72 pp. (also available at https://www.fao.org/publications/card/en/c/CA5131EN/).

513 **Sherwood, S., Schut, M. & Leeuwis, C.** 2012. Learning in the social wild: encounters between farmer field schools and agricultural science and development in Ecuador. *In*: *Adaptive collaborative approaches in natural resources governance – Rethinking participation, learning and innovation*, pp. 102–137. London, Routledge.

514 **Humphries, S., Holmes, T.P., Kainer, K., Koury, C.G.G., Cruz, E. & de Miranda Rocha, R.** 2012. Are community-based forest enterprises in the tropics financially viable? Case studies from the Brazilian Amazon. *Ecological Economics*, 77: 62–73. https://doi.org/10.1016/j.ecolecon.2011.10.018

515 **Wulandari, C. & Inoue, M.** 2018. The importance of social learning for the development of community based forest management in Indonesia: the case of community forestry in Lampung Province. *Small-scale Forestry*, 17(3): 361–376. https://doi.org/10.1007/s11842-018-9392-7

516 **FAO**. 2019. *Farmer taking the lead | FAO Stories | Food and Agriculture Organization of the United Nations* [online]. [Cited 12 January 2022]. https://www.fao.org/fao-stories/article/en/c/1199133/

517 **FAO**. Undated. *Business | Global Farmer Field School Platform | Food and Agriculture Organization of the United Nations* [online]. [Cited 8 December 2021]. https://www.fao.org/farmer-field-schools/ffs-overview/business/en/

518 **Rezaeinejad, I.** 2021. Impact online marketing strategies on improving the status of businesses in the COVID-19 Situation in Iran. *Asian Basic and Applied Research Journal*, 4(2): 24–33. (also available at https://globalpresshub.com/index.php/ABAARJ/article/view/1281).

519 **Piabuo, S.M., Tsafac, S., Minang, P.A., Foundjem-Tita, D., Guimke, G. & Duguma, L.** Undated. *Effect of COVID-19 on rural community enterprises – Case of community forest enterprises in Cameroon*. Nairobi, World Agroforestry – ICRAF.

520 **Tengö, M., Hill, R., Malmer, P., Raymond, C.M., Spierenburg, M., Danielsen, F., Elmqvist, T. *et al.*** 2017. Weaving knowledge systems in IPBES, CBD and beyond: lessons learned for sustainability. *Current Opinion in Environmental Sustainability*, 26–27: 17–25. https://doi.org/10.1016/j.cosust.2016.12.005

521 **FAO**. 2021. *Indigenous Peoples' food systems*. FAO, Alliance of Bioversity International, and CIAT. https://doi.org/10.4060/cb5131en

522 **Edwards, A., Archer, R., De Bruyn, P., Evans, J., Lewis, B., Vigilante, T., Whyte, S. *et al.*** 2021. Transforming fire management in northern Australia through successful implementation of savanna burning emissions reductions projects. *Journal of Environmental Management*, 290: 112568. https://doi.org/10.1016/j.jenvman.2021.112568

523 **Russell-Smith, J., Yates, C.P., Edwards, A.C., Whitehead, P.J., Murphy, B.P. & Lawes, M.J.** 2015. Deriving multiple benefits from carbon market-based savanna fire management: an Australian example. *PLOS ONE*, 10(12): e0143426. https://doi.org/10.1371/journal.pone.0143426

524 **Edwards, A., Archer, R., De Bruyn, P., Evans, J., Lewis, B., Vigilante, T., Whyte, S. *et al.*** 2021. Transforming fire management in northern Australia through successful implementation of savanna burning emissions reductions projects. *Journal of Environmental Management*, 290: 112568. https://doi.org/10.1016/j.jenvman.2021.112568

525 **Russell-Smith, J., Yates, C., Vernooij, R., Eames, T., van der Werf, G., Ribeiro, N., Edwards, A. *et al.*** 2021. Opportunities and challenges for savanna burning emissions abatement in southern Africa. *Journal of Environmental Management*, 288: 112414. https://doi.org/10.1016/j.jenvman.2021.112414

526 **Rekola, M., ed.** 2019. *Global outlook on forest education (GOFE)*. UN Educational, Scientific and Cultural Organization. (also available at https://foresteducation.wordpress.com/).

527 **Rekola, M. & Sharik, T.** 2021. *Global synthesis report on forest education*. Rome, FAO.

528 **FAO & Fund for the Development of the Indigenous Peoples of Latin America, and the Caribbean**. 2021. *Forest governance by indigenous and tribal peoples – An opportunity for climate action in Latin America and the Caribbean*. FAO. https://doi.org/10.4060/cb2953en

529 **FAO, International Union of Forest Research Organizations & International Tropical Timber Organization**. Forthcoming. *Proceedings of the International Conference on Forest Education*. (also available at www.fao.org/forestry/forest-education/conference/en).

530 **FAO**. 2018. *Agricultural services and digital inclusion*. www.fao.org/3/i7361en/I7361EN.pdf

531 **Philip, L. & Williams, F.** 2019. Remote rural home based businesses and digital inequalities: understanding needs and expectations in a digitally underserved community. *Journal of Rural Studies*, 68: 306–318. https://doi.org/10.1016/j.jrurstud.2018.09.011

532 **Schroeder, K., Lampietti, J. & Elabed, G.** 2021. *What's cooking – Digital transformation of the agrifood system*. Washington, DC, World Bank. https://doi.org/10.1596/978-1-4648-1657-4

533 **International Telecommunication Union**. 2020. *Measuring digital development – Facts and figures 2020*. www.itu.int/en/ITU-D/Statistics/Pages/facts/default.aspx

534 **Working Group on 21st Century Financing Models for Sustainable Broadband Development**. 2021. *21st century financing models for bridging broadband connectivity gaps*. Broadband Commission for Sustainable Development. 198 p.

535 **Misaki, E., Apiola, M., Gaiani, S. & Tedre, M.** 2018. Challenges facing sub-Saharan small-scale farmers in accessing farming information through mobile phones: a systematic literature review. *The Electronic Journal of Information Systems in Developing Countries*, 84(4): e12034. https://doi.org/10.1002/isd2.12034

536 **United Nations Secretary-General**. 2020. *Road map for digital cooperation – Implementation of the recommendations of the High-level Panel on Digital Cooperation*. United Nations. www.un.org/en/content/digital-cooperation-roadmap

537 **Harris, L. & Nordhaug, L.M.** 2021. *The Digital Public Goods Alliance's commitment to co-develop digital public infrastructure for an equitable recovery | Digital Public Goods Alliance* [online]. [Cited 25 March 2022]. https://digitalpublicgoods.net/blog/the-digital-public-goods-alliances-commitment-to-co-develop-digital-public-infrastructure-for-an-equitable-recovery

538 **Ivus, O. & Boland, M.** 2015. The employment and wage impact of broadband deployment in Canada. *Canadian Journal of Economics/Revue canadienne d'économique*, 48(5): 1803–1830. https://doi.org/10.1111/caje.12180

539 **Park, S.** 2017. Digital inequalities in rural Australia: a double jeopardy of remoteness and social exclusion. *Journal of Rural Studies*, 54: 399–407. https://doi.org/10.1016/j.jrurstud.2015.12.018

540 **Correa, T., Pavez, I. & Contreras, J.** 2017. Beyond access: a relational and resource-based model of household Internet adoption in isolated communities. *Telecommunications Policy*, 41(9): 757–768. https://doi.org/10.1016/j.telpol.2017.03.008

541 **FAO**. 2021. *FAO-EU FLEGT Programme success story – Innovative digital approaches to sustaining livelihoods through the production and sale of legal timber*. FAO. 2 p. (also available at https://www.fao.org/publications/card/en/c/CB4537EN).

542 **Poschen, P.** 2015. *Decent work, green jobs and the sustainable economy – Solutions for climate change and sustainable development*. Sheffield, Greenleaf Publishing [u.a.]. 182 pp. (also available at http://bit.ly/2O8YUUo).

543 **Bolin, A.** 2020. *Women's empowerment through collective action – How forest and farm producer organisations can make a difference*. FAO and International Institute for Environment and Development. (also available at https://doi.org/10.4060/ca8713en).

544 **Mwangi, E., Meinzen-Dick, R. & Sun, Y.** 2011. Gender and sustainable forest management in East Africa and Latin America. *Ecology and Society*, 16(1). https://doi.org/10.5751/ES-03873-160117

545 **Rights and Resources Initiative**. 2018. *At a crossroads – Consequential trends in recognition of community-based forest tenure from 2002–2017*. Washington, DC. https://doi.org/10.53892/UCYL3747

546 **Cruz-Burga, Z., Monterroso, I., Larson, A., Valencia, F. & Saldaña, J.S.** 2019. *The impact of formalizing rights to land and forest – Indigenous community perspectives in Madre de Dios and Loreto*. InfoBrief 242. Center for International Forestry Research. https://doi.org/10.17528/cifor/007156

547 **Durán, R., Monterroso, I. & Larson, A.M.** 2018. *Género e interculturalidad en la formalización de las comunidades nativas en Perú: Desafíos y recomendaciones*. Center for International Forestry Research. (also available at https://www.cifor.org/knowledge/publication/6916/).

548 **Bolaños, O.** 2017. *Los derechos de las mujeres indígenas y los desafíos para los proyectos de titulación de la propiedad comunal en el Perú: Resumen Político* [online]. Center for International Forestry Research [Cited 10 November 2021]. https://www.cifor.org/knowledge/publication/6543/

REFERENCES

549 **Jhaveri, N.J.** 2020. *Forest tenure pathways to gender equality – A practitioner's guide*. Center for International Forestry Research. https://doi.org/10.17528/cifor/007909

550 **Macqueen, D. & Campbell, J.** 2020. *Prosperity in place – Meaningful work for mobile youth that enhances forest landscapes*. Rome and London, FAO and International Institute for Environment and Development. (also available at https://pubs.iied.org/13615iied).

551 **Macqueen, D. & Campbell, J.** 2020. *Prosperity in place – Meaningful work for mobile youth that enhances forest landscapes*. Rome and London, FAO and International Institute for Environment and Development. (also available at https://pubs.iied.org/13615iied).

552 **Nanavaty, R., Desai, M. & Bhatt, M.** 2018. SEWA: developing a business incubation ecosystem for smallholders and forest producers in India. In: *Forest business incubation – Towards sustainable forest and farm producer organisation (FFPO) businesses that ensure climate resilient landscapes*, pp. 245–276. Rome, FAO and London, International Institute for Environment and Development. (also available at https://pubs.iied.org/13595iied).

553 **Macqueen, D. & Campbell, J.** 2020. *Prosperity in place – Meaningful work for mobile youth that enhances forest landscapes*. Rome and London, FAO and International Institute for Environment and Development. (also available at https://pubs.iied.org/13615iied).

554 **Holden, S.T. & Tilahun, M.** 2018. The importance of Ostrom's design principles: youth group performance in northern Ethiopia. *World Development*, 104: 10–30. https://doi.org/10.1016/j.worlddev.2017.11.010

555 **Herren, H.R., Bassi, A.M., Zhuohua, T. & Binns, P.W.** 2012. *Green jobs for a revitalised food and agriculture sector*. Rome, FAO. (also available at https://bit.ly/3pp7kbG).

556 **Macqueen, D. & Campbell, J.** 2020. *Prosperity in place – Meaningful work for mobile youth that enhances forest landscapes*. Rome and London, FAO and International Institute for Environment and Development. (also available at https://pubs.iied.org/13615iied).

557 **Moran, H.** 2018. FEDECOVERA: a cooperative business development exercise in Guatemala. *Forest business incubation – Towards sustainable forest and farm producer organisation (FFPO) businesses that ensure climate resilient landscapes*, pp. 91–110. Rome, FAO and London, International Institute for Environment and Development. (also available at https://pubs.iied.org/13595iied).

558 **Majurin, E.** 2012. *How women fare in East African cooperatives – The case of Kenya, Tanzania and Uganda*. Dar es Salaam, International Labour Organization. (also available at https://hdl.loc.gov/loc.gdc/gdcovop.2019352559).

559 **Bolin, A.** 2020. *Women's empowerment through collective action – How forest and farm producer organisations can make a difference*. FAO and International Institute for Environment and Development. https://doi.org/10.4060/ca8713en

560 **Allan, A., Ahern, B. & Wilson, M.** 2016. *The state of linkage report – The first global mapping of savings group linkage*. London, CARE, Plan and Barclays. (also available at https://care.ca/wp-content/uploads/2018/12/The-State-of-Linkage-Report-2016.pdf?x15040).

561 **FAO. 2021**. *Strategic Framework 2022–31*. (also available at www.fao.org/3/cb7099en/cb7099en.pdf).

562 **FAO**. 2018. *Transforming food and agriculture to achieve the SDGs – 20 interconnected actions to guide decision-makers*. https://www.fao.org/3/I9900EN/i9900en.pdf

563 **Vis, M., Mantau, U. & Allen, B., eds.** 2016. *Study on the optimised cascading use of wood.* No 394/PP/ENT/RCH/14/7689. European Commission. https://data.europa.eu/doi/10.2873/827106

564 **Kirchherr, J., Reike, D. & Hekkert, M.** 2017. Conceptualizing the circular economy: an analysis of 114 definitions. *Resources, Conservation and Recycling*, 127: 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

565 **Bocken, N.M.P., de Pauw, I., Bakker, C. & van der Grinten, B.** 2016. Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, 33(5): 308–320. https://doi.org/10.1080/21681015.2016.1172124

566 **FAO.** 2020. *Global Forest Resources Assessment 2020 – Main report*. FAO. https://doi.org/10.4060/ca9825en

567 **FAO**. 2020. *Global Forest Resources Assessment 2020 – Main report*. FAO. https://doi.org/10.4060/ca9825en

568 **Stanturf, J., Mansourian, S. & Kleine, M., eds.** 2017. *Implementing forest landscape restoration – A practitioner's guide*. Vienna, International Union of Forest Research Organizations.

569 **Millennium Ecosystem Assessment (Program), ed.** 2005. *Ecosystems and human well-being: synthesis*. Washington, DC, Island Press. 137 pp.

570 **Martínez Pastur, G., Perera, A.H., Peterson, U. & Iverson, L.R.** 2018. Ecosystem services from forest landscapes: an overview. *Ecosystem services from forest landscapes – broad scale considerations*, pp. 1–10. New York, USA, Springer Science+Business Media.

571 **International Labour Organization**. 2016. *What is a green job?* [online]. [Cited 16 November 2021]. https://www.ilo.org/global/topics/green-jobs/news/WCMS_220248/lang--en/index.htm

572 **De Beer, J.H. & McDermott, M.J.** 1989. *The economic value of non-timber forest products in Southeast Asia - With emphasis on Indonesia, Malaysia and Thailand*. Amsterdam, the Netherlands, Netherlands Committee for IUCN.

573 **Shackleton, C., Delang, C.O., Shackleton, S. & Shanley, P.** 2011. Non-timber forest products: concept and definitions. *In*: S. Shackleton, C. Shackleton & P. Shanley, eds. *Non-timber forest products in the global context*, pp. 3–21. Tropical Forestry. Berlin, Heidelberg, Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-17983-9_1

574 **FAO.** 1999. Towards a harmonized definition of non-wood forest products. *Unasylva*, 50(198): 63–64.

2022
THE STATE OF THE WORLD'S FORESTS

FOREST PATHWAYS FOR GREEN RECOVERY AND BUILDING INCLUSIVE, RESILIENT AND SUSTAINABLE ECONOMIES

Against the backdrop of the Glasgow Leaders' Declaration on Forests and Land Use and the pledge of 140 countries to eliminate forest loss by 2030 and to support restoration and sustainable forestry, the 2022 edition of *The State of the World's Forests* explores the potential of three forest pathways for achieving green recovery and tackling multidimensional planetary crises, including climate change and biodiversity loss.

The three interrelated pathways are halting deforestation and maintaining forests; restoring degraded lands and expanding agroforestry; and sustainably using forests and building green value chains. The balanced, simultaneous pursuit of these pathways can generate sustainable economic and social benefits for countries and their rural communities, help sustainably meet increasing global demand for materials, and address environmental challenges.

The State of the World's Forests 2022 presents evidence on the feasibility and value of the pathways and outlines initial steps that could be taken to further pursue them. There is no time to lose – action is needed now to keep the global temperature increase below 1.5 °C, reduce the risk of future pandemics, ensure food security and nutrition for all, eliminate poverty, conserve the planet's biodiversity, and offer young people hope of a better world and a better future for all.

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